NUCLEAR ENGINEERING

VOL. 2 NO. 17 AUGUST, 1957

PRINCIPAL CONTENTS

page

METALLURGICAL INFORMATION—ITS USE IN NUCLEAR ENGINEERING By Alex. B. McIntosh
Renseignements Métallurgiques dans la Technique Nucléaire
Wissenswertes aus der Metallurgie für den Atomkraft-Ingenieur
Información Metalúrgica en la Ingeniería Nuclear 311

REMOTE VIEWING By F. S. Bloxam
Examen a Distance
Fern-Beobachtung
Visionado a Distancia 315

BRITISH REACTORS—REFERENCE LIST 320

CHEMICAL PROBLEMS IN COOLANT GASES By W. E. Dennis
Problems Chimiques des Gaz Refrigerants
Chemische Probleme bei der Gas-Kühlung
Los Problemas Quimicos de Gases de Engriamiento 321

BOILER CIRCULATION RESEARCH
Recherches sur la Circulation des Chaudieres
Forschung über den Umlauf in Kesseln
Investigaciones Sobre la Circulacion deu Aga en Calderas 324

THE APPR ; PROBLEMS AND THEIR SOLUTIONS 330

NUCLEAR ENERGY IN HOLLAND
L'Energie Nucléaire en Hollande
Atomkraft in Holland
Energia Nuclear en Holanda 327

THE A.E.A. ANNUAL REPORT 338

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REGULAR FEATURES

EDITORIALS 307
COMMENTARY 309
TECHNICAL PAPERS . . 335
WORLD NEWS 339
PERSONAL 342
ORBITS IN INDUSTRY . . 344
INDUSTRIAL NOTES . . 345
PROCESSES AND EQUIPMENT 347
PATENTS REVIEWED . . 350

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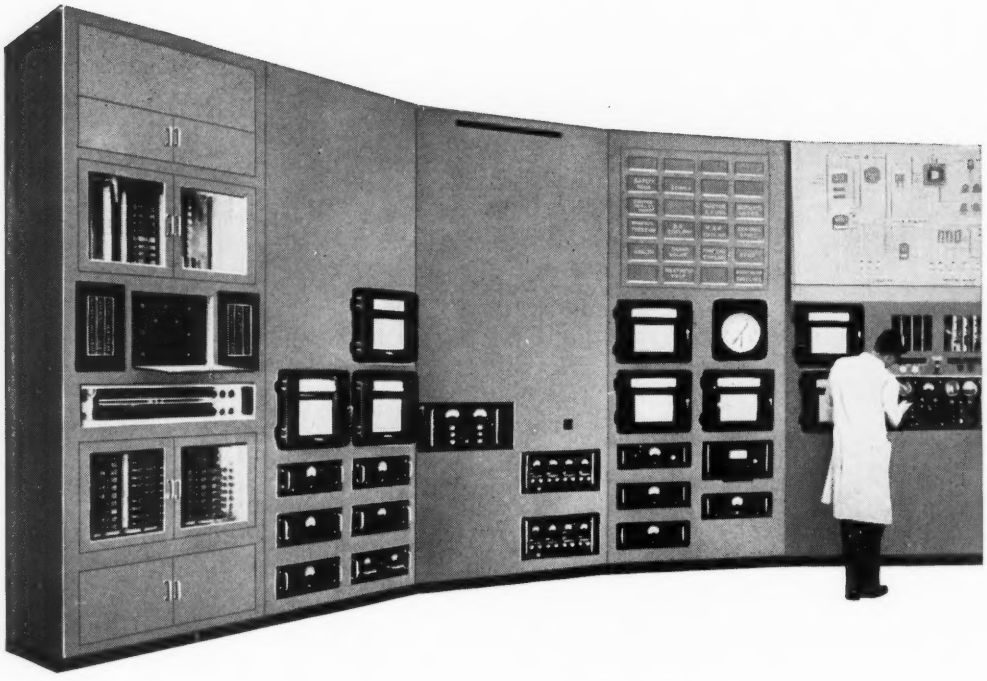

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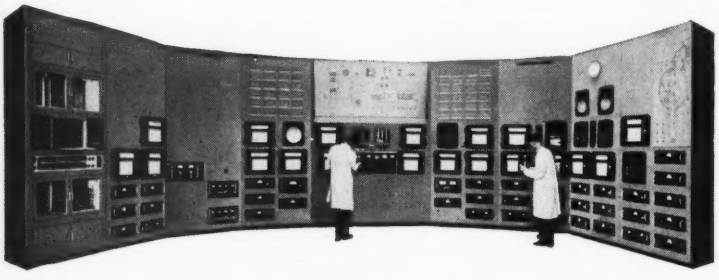

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NUCLEAR ENGINEERING VOL. 2 NO. 17 AUGUST, 1957

Industry and the C.E.A.

CONCERN has been expressed in some quarters (if not inside the consortia) at the possibility of equipment for nuclear power stations being supplied only by a predetermined group of companies. If the C.E.A. were to continue to place contracts for complete power stations it could prove a serious limitation for companies not formally associated with the " Big Five ": even when tendering for sub-contract work such companies would be at a disadvantage when compared with those within the groups. Furthermore, opportunity for gaining experience in the nuclear field would be small and, in effect, competitive tendering would become impossible.

Break with Tradition

In the past, the C.E.A. has been at great pains to ensure an even distribution of effort, and has even gone so far as to reject the lowest tender for a particular item in order to avoid placing too large a contract with one concern and thus becoming unduly dependent by having too large an amount invested at one time in one company. The industry has, on the whole, accepted this policy with understanding, even though it may have considered that at times this philosophy has been pursued with unnecessary vigour. Present policy with nuclear stations is thus at complete variance with tradition.

It would be wrong, however, to assume that this state of affairs will last indefinitely. The C.E.A. has not been acting as an independent agent; the formal establishment of consortia was demanded by the A.E.A. and with the absolute bargaining power that it possessed (in terms of know-how, uranium, and graphite) there was no alternative. For the "crash " programme envisaged there was also no alternative, for the consortia concept was the only one which could produce the answers with the necessary speed. But the C.E.A. is not merely concerned with the commissioning of designs, it is faced with the construction of an increasing number of power stations. Whilst the A.E.A. has been largely responsible for vetting the designs it is the C.E.A. which is responsible for construction and finance. Now that the first contracts have been placed the apparent tacit acceptance of the enforced set-up—not to mention reticence on the matter of future contracts—has been surprising, and not a little disturbing, leaving the impression that the C.E.A. is not in a position to formulate its own purchasing policy.

B.E.P.C. Warning

Some indication of the C.E.A.'s opinion on the matter was given, however, at the British Electrical Power Convention when, in effect, a warning was issued. While acknowledging the necessity, even the desirability, of highly integrated design groups, the tendency to confine constructional effort to within the groups was deprecated. Whilst the C.E.A. is prepared to accept the present situation for the time being, unless the big groups are prepared to sub-contract work outside, the C.E.A. will step in and insist on handling the placing of the contracts, once the basic design is agreed. In addition the groups were warned that the C.E.A. was not prepared to initiate a programme of nuclear building which would saturate the design and constructional efforts of the groups. Although the groups could count on a steadily increasing building programme, they must look for other markets to satisfy their potential production.

For those who have a regard for the U.K.'s export programme this assurance comes as a considerable relief, particularly when contrasted with a comment (made by one of the groups at the same conference) that, unless the C.E.A. was prepared immediately to guarantee a greater programme than that already laid down, the groups would be forced to export reactors.

Leaving aside the importance of our exports the C.E.A. clearly cannot allow a situation to arise when competition between contracting consortia is purely academic in character and orders must be placed in strict rotation. What is, however, required of the C.E.A. is a more forthright enunciation of its policy towards outsiders. If, however, policy cannot be finalized and must await the new Electricity Bill and a definition of the powers of the Generation Board, then at least more official pointers to the future should be given; companies both within and without the consortia have a right to know where they stand.

The Role of Consulting Engineers

THE controversy concerning the exact role of consulting engineers in the field of power station design and construction is not new; it has often been said in the past that the days of consultants are numbered. The problem has been brought to a head at the present time, however, by the advent of nuclear generation and, particularly, by the formation of the present industrial groups, who are now in a position to undertake the design and construction of complete nuclear power stations.

The Rise of the Consultant

Consulting engineers emerged and flourished at the beginning of the present century, in the very early days of electricity supply systems, and were usually formed as professional partnerships of two or three individuals. They were able to earn a successful living by selling their technical knowledge at a time when engineering education hardly existed. Their clients were generally small firms or municipal authorities who were not in a position to employ a competent technical staff of their own. The schemes which these consultants handled in the early days were, of course, of a very modest and simple nature compared with the large power stations and transmission systems of today.

The real cause of the decline in status of the consulting engineer in recent years may be traced to the failure of electrical and mechanical consultants to retain their former lead in technical knowledge; their failure generally to build up any adequate staff and organization appropriate to the ever-increasing size and complexity of electrical power schemes; and, above all, in their failure to accept responsibility for the design of any plant.

Civil Engineers Not Affected

It should be noted, however, that *civil* engineering consultants have largely succeeded in maintaining their status, because they do actually design and accept responsibility for their dams, tunnels, bridges, and other engineering structures. With electrical and mechanical engineering, on the other hand, responsibility is carried by the manufacturers who design, construct, and install the plant. The task of the consultant nowadays is little more than that of ensuring that individual items of plant supplied by different contractors do, in fact, fit together.

Another factor in the tide that has been flowing against the consultants has been the growth of the large state-controlled electricity authorities and, particularly in the United Kingdom, the formation of the Central Electricity Authority. An organization of the size of C.E.A. can clearly afford to employ a permanent engineering staff to handle all the negotiations and planning which in the past might have been covered by consulting engineers. Finally, the Atomic Energy Authority has entered the scene and has established itself, quite rightly, as the fountain-head of technical knowledge in the nuclear field. The U.K.A.E.A. now performs, among its other duties, the role of a super-consultant in nuclear matters.

No Turning Back

The question remains, therefore, whether there is anything left for the traditional consulting engineering firms to do. Certainly there can be no turning back to the old-fashioned system of a multiplicity of individual contracts with co-ordination by the consultant. The closely integrated nature of any nuclear power station design, together with the complex inter-relation between different parts of the plant, makes it absolutely essential to adopt the principle of a single design responsibility for the entire station. Design in the nuclear field cannot be divorced from development and manufacturing resources, so that the main design responsibility can only be exercised by the recognized industrial groups. Any attempt to disrupt this principle can have only an adverse effect on the United Kingdom's progress in the nuclear field.

If, however, the consultants are willing to adapt themselves to this new situation there may still be a useful role for them to play. Not all purchasers of nuclear power plant will have the resources in technical staff of the Central Electricity Authority. Some of the smaller authorities, and also some overseas purchasers, may well feel the need of an independent engineering organization to conduct technical negotiations on their behalf and to provide an inspection service. This will not be an easy task to perform, partly because of the legacy of antagonism from the past between consultants and manufacturers, and partly because the U.K.A.E.A. will be concerned with the nuclear aspects of any project and will probably be unwilling to act through the agency of a third party.

New Outlook Required

In spite of these obstacles, however, the consultants have something valuable to contribute in their reputation of independence and impartiality. Every effort should therefore be made to achieve a new understanding between the industrial groups, the U.K.A.E.A., and the consultants, which will take account of the facts of the present situation. There is no reason why this should not be done—without any sacrifice of real independence—if the consultants will abandon the pretence of the past and accept a minor but useful role for the future.

Commentary

Atomic Energy in France

As a result of a recent invitation to visit atomic energy installations in France and the opening of the Marcoule site to the Press it has been possible to obtain a first-hand estimate of the scale of French atomic energy effort and to view its development programme in the proper perspective.

The responsibility for atomic energy development in France is invested in the Commissariat à l'Energie Atomique (C.E.A.) which was first created in 1945. It was not, however, until 1952 that the first five-year plan was launched, this being given additional impetus in 1955 by a significant increase in the finance available. In April this year the second five-year plan was approved by the National Assembly. Terms of reference of the C.E.A. are wide and, with credit voted on a long-term basis, it is reasonably independent of the changing political situation.

Whilst the C.E.A. is responsible for developments in atomic energy, Electricité de France (E.D.F.) is responsible for the erection of nuclear power stations. The C.E.A. is the only body with the powers to build reactors, but these powers can be delegated and, with the C.E.A. as consultants, E.D.F. is the effective authority on the design and construction of the C.E.A. is by the Comité de l'Energie Atomique. opportunity of developing its own resources than in the United Kingdom, and has, in general, acted as constructional contractors only. At Marcoule, for example, all design work was undertaken by the C.E.A., except for certain detail work on the conventional side which has been left to E.D.F. or industry.

So far, two consortia have been formed in France; Indatom, comprising 10, and France Atom, comprising 14, companies; only Indatom, however, has a central nuclear engineering organization of any significance. Administration of the C.E.A. is by the Comité de l'Energie Atomique. Members of this are high Government officials or outstanding representatives of the scientific and industrial worlds, and the chairman of the committee is the Premier, or the Minister or Secretary of State designated by him. The committee has an Administrator-General and a High-Commissioner in the persons of Monsieur Francis Perrin and Monsieur Pierre Guillaumat; these are assisted by a scientific council, a mines committee, an industrial equipment committee and various consultative bodies, providing links with Government institutions, universities, and industry.

Establishments

Ore treatment plants have been constructed, or are in the course of construction, at Gueugnon, Ecarpiere, and Bessines, with potential outputs of 300 tons, 200 tons and 450 tons per year respectively of uranium as concentrates. It is anticipated that production of uranium metal will amount to 500 tons in 1958, rising to 3,000 tons per year in 1975. Refining of this metal is performed at the Le Bouchet factory, which is also capable of handling the ores from Madagascar; these may contain up to 70% thorium, 20% uranium. Some research and development is also conducted at Le Bouchet, notably on the chemistry side.

Whilst the original research into atomic energy was concentrated at Chatillon, and France's first reactor was completed here in 1948 (a natural uranium heavy water reactor EL1), the bulk of research is concentrated at Saclay. Pilot plant work, however, for the plutonium factory at Marcoule was undertaken at Chatillon. Saclay, nevertheless, is the French equivalent of Harwell, the present complement being over 2,000, and increasing steadily. One of the first projects at Saclay was the construction of a natural uranium heavy water moderated reactor, employing gas cooling (originally nitrogen, now carbon dioxide); this reactor, with a maximum flux of approximately 10^{13}/cm^2-sec. is capable of operating at a maximum power of some $2\frac{1}{2}$ MW.

The heavy water reactor EL3 (roughly equivalent to Dido at Harwell) became critical on July 8 this year; this will provide more facilities for irradiation work and will permit the initiation of a serious programme of in-pile experimentation. A third research centre is nearing completion at Grenoble an area with very active university and industrial facilities; this establishment will be closely linked with the research centre at Saclay.

Marcoule is roughly the equivalent of the Windscale-Calder site, being the location for the plutonium extraction plant (which, begun in June 1955, is due to go into operation at the end of this year), G1 (the first gas-cooled graphite-moderated reactor in France, commissioned in January, 1956, rated at 40 MW and now, incidentally, generating 5 MW electricity), and G2 and G3 (designed primarily for plutonium production but also for power generation). Both reactors, begun in November 1955, are rated at 150 MW heat and 25 MW net electricity. G2 is due for commissioning in Spring 1958 and G3 six months later. Total plutonium production from the site will amount to approximately 100 kg/y.

Programme of the Commissariat

Compared with the United Kingdom, France began the post-war development period with an equivalent pressing demand for the immediate installation of nuclear power stations, but with much less experience in the field of atomic energy. Certainly, in the late 1940s, there was neither the knowledge nor the effort available for the building of a diffusion plant. France was therefore committed to a natural uranium programme. Prospecting revealed the presence of considerable deposits of uranium within her territories, and the main effort was initially concentrated on the development of uranium mines and in the construction of plants able to process and refine. It was felt, however, that it was essential to have a source of enriched fuel, and it was concluded that plutonium offered greater economic advantages than U_{235} produced in a gaseous diffusion plant. Although the impression is given that the Marcoule reactors have been built for the production of plutonium solely for the fuelling of enriched reactors, military considerations must have played some part, at least, in easing the financing of the project.

In more recent times opinion has changed and it seems certain that France will ensure that she has direct access to a diffusion plant in the future. This would be a small nationally owned plant if Euratom does not undertake the construction of a large unit.

In addition to the production of natural and enriched

fuel, a programme of research and development was instituted to allow the design of power reactors to be undertaken. These—EDF1, due to commence operation in mid-'59, followed in 1960 by EDF2—are under the jurisdiction of Electricté de France and are being constructed at Chinon on the Loire. Net electrical output is scheduled as 60 MW for the first and 100-200 MW for the second.

Apart from the research reactors at Chatillon and Saclay work has been concentrated on the gas-cooled graphite-moderated system. Internal supplies of reactor-grade graphite are considered adequate, although some hold-up may be encountered in uranium supplies.

Progress in Design

The engineering approach to the system has changed progressively from G1 to G2 and G3 (which are identical), and from these two to EDF1. G1 can be considered as being equivalent to something between BEPO and the Windscale reactors, but with a central entry inlet for the gas coolant.

When the design of G2 was considered (this reactor being more nearly akin to Calder Hall) it seemed advisable to gain experience in the construction of power reactors and pressurize the system. Considerable experience was available in France on pre-stressed concrete techniques and it was decided to use this construction for the pressure vessel. Calculations showed that the demands of biological shielding would be greater in terms of concrete thickness than the strength necessary to contain the design pressure of 15 at m. (215 p.s.i.) Doubts were expressed at the practicability of stacking fuel elements vertically and horizontal fuel channels were therefore adopted as for the reactor G1. Control rods are vertical but the distortion of the flux that this implies is not considered to be of serious import. It was recognised that the concrete could not be made completely gas tight and a steel lining is included for this purpose. It should be emphasized however that this is a seal and in no way a pressure shell. The inner concrete face is kept substantially cold (50°C) by a separate CO_2 circuit, detailed information of the effect of high thermal gradients not being available. The horizontal channel system allows fuel elements to be charged at one end and discharged at the other, and this can be undertaken on load.

When extrapolating this design to EDF1 a strong body of opinion felt that comparable experience should be obtained on the use of steel pressure vessels. Greater experience on the fabrication of fuel element cans permitted the move to vertical channels and this form would also reduce the vessel diameter for a given core reactivity. In consequence the cost difference between a concrete and steel pressure vessel was not large. Other engineering considerations such as additional load support, sealing of the vessel confirmed the view that steel should be investigated in more than a theoretical manner.

EDF1 reactor is thus not unlike Calder Hall. Uranium investment is similar, but the pressure is increased to 25 atm., requiring a vessel wall thickness of 107 mm. Treatment of the biological shield is likely to be novel in that a spherical outer shape is envisaged to provide complete containment of the active circuits. The additional cost of this is not large and the experience afforded is felt to be of considerable value.

Heat exchanger philosophy is also unlikely to be the same as in the U.K. calling for a large number of small units rather than a small number of large units. Charge and discharge under pressure will be provided.

The core is expected to use longitudinally-finned magnesium cans, containing hollow uranium rods in the centre of the core and solid rods on the outside. The introduction of thorium into the core blanketing is also being considered. Bottom charging of the reactor is not ruled out, but it is interesting to note that whereas with the plutonium production units charging will be done on load, it is felt unnecessary to introduce this complication into the charging mechanism of EDF1. EDF2, scheduled for completion in 1960, is likely to have a fuel investment of 250 tons. Coolant gas in all cases is carbon-dioxide.

The decision to abandon the pre-stressed concrete in favour of the steel pressure vessel is not necessarily a final policy as regards to future reactors, i.e., subsequent to EDF2; the C.E.A. and E.D.F. propose to await experience gained on G2 and G3 and EDF1 and 2 before committing themselves to a definite decision.

Advanced Reactors

The main research in this field is of fundamental character only, in that development of the advanced reactors is likely to be a communal effort with other countries, either through the organization of O.E.E.C. or Euratom. A zero energy homogeneous reactor fuelled with plutonium sulphate is, however, to be built at Saclay later this year and the development of a breeder system is considered to be of major importance.

The active operation of Euratom will also have a considerable influence on the internal power reactor programme as the plan outlined by the Three Wise Men calls for something like a 50% increase over that originally envisaged by E.D.F. (8000 MW by 1975). Although the E.D.F. scheme was considered to be a minimum programme it is nevertheless felt sufficient to provide adequate incentive to French manufacturing resources. In general terms, advanced reactor research follows the broad lines of Britain and the United States, but must be considered to be on a relatively small scale.

Industrial Participation

Industry's contribution to the projects at Marcoule and at Chinon are similar to those at Chapel Cross and Calder Hall, i.e., industry is acting almost entirely as building contractors to the designs of the two Authorities. E.D.F. proposes to contract for nuclear power stations on much the same terms as for conventional stations, in contrast to the Central Electricity Authority's present policy in the U.K. Independent projects are, however, in hand by the two French consortia. Indatom has received from the C.E.A. a contract to complete the feasibility study by the end of this year for a gas-cooled graphite or heavy water-moderated propulsion unit suitable for installation in a 40,000-ton tanker. Design includes the whole of the propulsion unit and an auxiliary steam generator and turbine. At the same time, France Atom is conducting a competitive study for a pressurized water and a boiling water unit. Indatom is also constructing at Grenoble and Chatillon swimming-pool reactors and is making proposals to the Netherlands for the construction of a sodium-graphite reactor. France Atom is preparing a plan of a gas-cooled reactor for the Netherlands.

The Navy

Independently of the above projects, the Navy is undertaking the construction of a nuclear-propelled submarine which will probably be powered by a pressurized heavy water reactor. It is difficult to assess the scale of the effort on this project.

Metallurgical Information—

Its Use in Nuclear Engineering

By ALEX B. McINTOSH,
Ph.D., B.Sc., F.R.I.C.
(Head of Culcheth Laboratories, U.K.A.E.A.I.G.).

The nuclear engineer, in his search for the optimum materials for reactor construction, has available many sources of data. Frequently these data may be conflicting or even inaccurate. Critical selection can, however, be made from an understanding of the importance of each specific chemical, physical or metallurgical property with respect to reactor design.

POSSIBLY because it is the youngest field of power engineering, there is with nuclear power an almost unique relationship between the engineer and the metallurgist. The latter's responsibility, particularly in the earliest stages of a project, is recognized from the outset, for the engineer depends on him for recommendations about materials and information which will allow him to carry out his designs.

The Main Aspects

Three types of material for which engineering demands arise can be distinguished. Uranium, thorium and plutonium stand alone in the first as materials suitable either as fuel or breeders of fuel. In the second are materials which have either a high or a low absorbing power for neutrons and are used specifically for applications where such properties are necessary. The high absorbing power materials are used for control or safety and the low where the minimum interference is essential with the neutron distributions on which the chain reactions depend. In the third class, materials which have been in normal engineering use for generations are called upon to meet conditions which are more exacting than any for which they have previously been used.

The engineer is concerned with designing the most efficient system for the production of heat by the fission of a heavy atom, and the conversion of this heat into electrical power by a method largely dependent on the temperature at which the heat is produced. In this country there is a preference for systems in which a uranium fuel is cooled by carbon dioxide which carries the heat through ducts to a heat exchanger from which steam is taken to a turbo-generator system. The economics of the system indicate the minimum life which is acceptable, and the metallurgist must guarantee the behaviour of materials for some such period.

During service the worst conditions of neutron flux, temperature, stress and corrosion factors are encountered by the fuel element in the fission zone, and the most important assurances to be given relate to the fuel element and the containing vessel in which the core is located. Away from the fission zone local conditions may be less severe and in the heat exchanger, for example, it may be possible to draw on the experience of more conventional power systems. Because the heat transfer fluid returns to the fission zone, and must not carry with it any contamination likely to interfere with the neutron economy or with the reactions which determine the steady state conditions of stability, some qualification of conventional practice may be necessary.

The purpose of this article is to consider the sort of information which engineers demand, but also to suggest aspects of metallurgical significance not commonly appreciated.

APPLICATION

The application of a metal depends on a suitable combination of properties. As an example of this, magnesium has been used as a canning material and could be said, after limited examination, to be obviously suitable for the application. Limited development work only was necessary, directed mainly to large-scale production of materials of sufficient purity, improved methods of welding and enhanced corrosion resistance.

Zirconium, considered for the same application, suffers from the disadvantage of excessively poor resistance to the oxidizing attack of cooling gases. Much more extensive development programmes are necessary before its greater potential, due to its much greater melting point, can be realized.

Apart from such proved and favoured applications, some property of a comparatively unknown metal may indicate a possible use, although no experience exists. As an example of this some rare earth metals such as samarium and gadolinium possess high absorption cross-sections for thermal neutrons, and this opens up a possible field of application in shielding alloys. The exploitation of new materials may result from imaginative yet responsible comment made on the basis of extensive experience.

OCCURRENCE

The geographic occurrence and the mineralogical nature of naturally occurring deposits indicate the availability of a specific metal. Some metals may possess advantageous properties but not be available. For example, gallium presents attractive properties for use as a liquid-metal coolant, but it is so scarce that it must be ruled out.

The mode of occurrence also shows which metals co-exist and which of these are likely to remain as contaminants. In some cases the separation of such contaminants requires expensive and complicated processing, adding greatly to the cost of the metal. Zirconium, for example, contains hafnium which has almost identical chemical properties. For most purposes this need not be separated, but if zirconium is to be used because of its thermal cross-section, hafnium must be rigorously excluded. Similarly with

tantalum and niobium, the presence of tantalum with the niobium would not normally be of consequence, but when the lowest cross-section is required, complete separation is essential.

EXTRACTION

An engineer is not normally interested in the method of extraction of a metal, except in so far as it affects the use and cost. Concern may be shown in the relationship of cost and purity because it is uneconomic to pay unnecessarily for a pure metal when a lower standard would suffice.

PHYSICAL PROPERTIES

The main physical properties governing the use of metals in nuclear power engineering are neutron capture cross-section, thermal conductivity, thermal expansion, specific heat, crystal structure, phase changes, density, vapour pressure, diffusion, permeability and melting point.

Different sources of information may give values of these parameters at variance, and this is frequently due to impurities. Only too often the value of information is reduced because the composition of a metal for which properties are quoted is not stated. Only after all sources of information have been scrutinized thoroughly in the light of experience can a critical selection of data be made and the best information quoted.

The importance of critical selection can be judged from the case of magnesium, for which the best value of capture cross-section up to about 1947 made it inferior to aluminium. During 1948 more trustworthy determinations became available and its superiority as a canning material was immediately evident, leading to its use in the carbon dioxide-cooled reactors of Calder Hall.

Care in selection is particularly necessary with the thermal conductivity, thermal expansion and specific heat, because these are basic properties used in arriving at assessments of the thermal output of a reactor and the thermal stressing of cans.

Crystal Structure

The value of information on crystal structure and phase changes lies in settling questions of fuel operating temperatures and behaviour. Although these are more important in the fission zone, they are of consequence in other parts of the circuit where changes of temperature occur.

The finalizing of dimensions depends largely on the density and with some components this parameter may have an overriding influence, as with removable shielding where crane capacities are limited. Where a necessity arises to reduce the power to weight ratio, density may exceed most other things in importance.

The vapour pressure of a metal is not usually considered of engineering importance, but within the fission zone of a reactor where the operating temperature may be fairly close to the melting point of the metal, circumstances are different, particularly when the metal forms an adherent and coherent oxide skin. When the vapour pressure is high enough the oxide can be disrupted, resulting in a change in the oxidation law and, in some cases, ignition. Thus, the vapour pressure can influence the highest fuel temperature which may have to be limited on this account.

Diffusion and permeability gain importance with some coolants, such as hydrogen or water where diffusion of hydrogen through the materials may cause degradation in their properties.

Melting Point

The melting point of a canning metal may be one of the dominant factors in the fission zone of a reactor enforcing a limitation on operating temperature, because the strength properties fall off. Other things such as neutron absorption being acceptable, the higher the melting point the higher the operating temperature. In this way zirconium and beryllium are superior to magnesium and aluminium. For a liquid-metal coolant the melting point should be as low as possible, both to avoid unnecessary heating and to economize in pumping power by ensuring the lowest viscosity.

MECHANICAL PROPERTIES

In the design of reactor components, values of mechanical properties as specific temperatures are used, but the effect of changing temperature and composition may be of greater value in explaining or forecasting the behaviour of the materials. Established engineering design relationships make use of the elastic and shear moduli, but the same parameters give some indication of the accommodation of imposed strain. The less the modulus the greater is the amount of strain which can be accommodated elastically before persistent deformation occurs. Thus, a lower modulus may be valuable in a fuel or can.

The limit of proportionality, yield stress and ultimate stress are of proved engineering value. For components such as the reactor pressure shell these tensile properties form the basis of the design, although the changing values of the properties with temperature give the best indication of the performance.

Ductility

In almost every engineering part, ductility is a valuable property not only at room temperature, but at elevated temperatures. As an example, the ductility of some alloys of magnesium may reach a low value at temperatures of the order of 200°C. For use at such temperatures special treatment may be needed so that the composition and grain size can be adjusted to ensure that the design conditions are met. In any deformation process the ductility shown is dependent on the rate of straining and the behaviour of materials under low rates of straining leads to the study of creep. Tensile properties and ductility at any temperature may indicate the behaviour of material when short-term deformations are involved, such as in some fabrication processes. Changes of constitution brought about at higher temperatures as in welding or fabrication may cause deterioration in ductility at normal or sub-normal temperatures. With pressure shells the occurrence of low ductility with falling temperature during fabrication and assembly shows a susceptibility to brittle fracture, and imposes severe limitations in the choice of a steel.

Change of ductility at any temperature with time may disclose that the material is liable to strain ageing or precipitation hardening. In structures such as reactor pressure shells such changes may be accelerated or intensified during the life of the component due to the effects of irradiation.

The ductility at rupture is frequently a much more important criterion. This is because in some engineering steels designed specially to give low extension over long periods there is, with time, a diminution in ductility such that, although the total extension calculated on the rate of extension may be permissible, the steel would fail before the maximum time elapsed. Such changes may be due to a number of metallurgical causes. It is usually, therefore, much more important to know the relationship between ductility at rupture and the stress to cause rupture at any temperature than it is to know whether an extrapolated figure is within the allowable creep extension.

Extrapolation of Creep Data

Difficulty always arises in deciding when the extrapolation of data is valid. Too frequently it is assumed that an extrapolation is valid without realizing that fundamental creep mechanisms are subject to change with time. The only absolute test is one of the same length as the prospective life of the component. This sort of test is rarely, if ever, possible so that a decision must be taken on the amount of extrapolation used. Based on sound metallurgical knowledge of the alloy in question, speculation can be made that the type of metallurgical change will not alter during a further period equal to some multiple times the period of test. The combined effect of ductility and creep cannot be separated. In every case when the alloys are subject to precipitation, the effect of strain ageing may cause deterioration in the ductility values, with the possibility of premature failure. With uranium, which is anisotropic, a complication is introduced by the Cottrell effect when the fuel is being irradiated and at the lowest rates of stressing creep takes place.

The whole behaviour of a material in creep is so complex that the greatest caution should be exercised and any creep law which claims to be universal should be viewed with the greatest reserve.

The importance of creep data and of obtaining reliable extrapolations is illustrated in the choice of steel for pressure shells. It has been calculated that the charging and discharging arrangements may be seriously affected if the extension in the steel exceeds 0.2% in 200,000 hours. To prevent uneconomic duration of test, and yet allow continuing improvements in design by the use of higher strength materials, any creep programme must be supported by extensive laboratory investigation, including the effects of irradiation, designed to disclose likely changes of creep mechanism and hence the range of valid extrapolation.

Hardness

Because the hardness of a metal is so easily measured by some indentation technique and so frequently is it the only non-destructive test which can be applied to a component, it is often used to give an overall indication of the stress bearing capacity or purity. With mild steel, experience has shown a quantitative relationship between the tensile properties and the hardness. In other metals such relationships may not be valid and should be viewed with suspicion until proved.

As a bearing or as one of two surfaces rubbing together, the use of a metal may depend on the maintenance of a hardness differential between them, and usually the part which can be replaced more easily is made the softer so that it should wear away.

With many metals the hardness is sensitive to the amount of impurity, either in solution or as discrete impurities. The change of hardness with composition gives often the best and easiest indication of the appearance of a second phase, resulting in an unacceptable change in other mechanical properties.

When deformation characteristics depend on the purity, the hardness forms a convenient guide for control. With niobium, for example, the amount of work hardening during deformation is a certain guide to the purity, and is the greater the more impure the material.

COMPATIBILITY

Compatibility means that combination of properties which enables materials to exist in contact with one another without chemical or metallurgical interaction. Although, ideally, compatibility implies total absence of reaction over a range of temperature beyond that likely to be experienced, some departure may be tolerated if the reactants can be kept apart, say, by the use of artificial protective layers. Compatibility may be the main criterion for a metal as a can and may limit the highest temperature at which a particular reactor can be operated. It depends first on the mutual solubilities or inter-reactions of the container metal, fuel and moderator. These need not be large to give rise to dissolution of a can into a liquid-metal coolant, absorption of the can into the fuel, or general deterioration of the mechanical and physical properties of the can. The best indication of the solubilities is obtained from the appropriate equilibrium diagram, but when the diagrams are not available, metallurgical theory may give some guidance. Low melting points or eutectics formed with fuel or coolant may make a material unsuitable as a container. The information is best obtained from equilibrium diagrams, but the known behaviour of other elements in the same sub-group of the periodic table also provides a guide. The container may develop a surface film which prevents solution or further reaction, but so that the container metal should be satisfactorily protected such a film must be stable in the presence of the fuel and coolant and be both coherent and adherent. The presence of impurities in the coolant may affect the compatibility of the container because the impurities may enter into reaction. As an example, the presence of oxides in liquid metals, hydrogen and sulphur-bearing compounds in gaseous coolants cause undesirable reactions. Grain boundary diffusion by a liquid metal can lead to intergranular attack or even, if accompanied by stress, to fracture. If the fuel is inert to the coolant, diffusion through the can may not be dangerous, but if compounds are formed with uranium through the diffusion of oxygen, nitrogen, or hydrogen, the consequences may be serious. Even when the solubility of the coolant in the container metal is low, diffusion can occur.

Compatibility with normal engineering materials such as copper, aluminium alloys, solder, lead, steels and other alloys should be confirmed because these can accidentally find their way into or onto a can.

Fortuitous Contamination

Because a reactor core is normally reckoned to be inaccessible for inspection or maintenance, compatibility in the fission zone is of the greatest importance, but although other components may be isolated and inspected during life, incompatibility of any components in these parts may lead to contamination being carried back to the core with the coolant. For that reason the possibility of inspection during life does not diminish the need to specify materials which are compatible.

In the fission zone of a thermal reactor the compatibility of the moderator with the coolant and the can is of equal importance to that of the container. When the gas temperatures are higher than in Calder Hall there is the possibility that reaction of the carbon dioxide coolant with graphite will lead to the formation of carbon monoxide and cause mass transfer with the deposition of carbon on cooler parts of the circuit. In this event some .neans must be found either of reducing or preventing the reaction. If a method of containing the graphite to separate the reactants is contemplated, the selection of the containing material, apart from any question of nuclear properties, will depend on its compatibility in turn with the moderator, the coolant and other materials with which it may come in contact.

The whole question of compatibility cannot be rated too highly. It is not sufficient to carry out static experiments. Determinations must be made under conditions of flow and

irradiation similar to those to be experienced. Because the expense of carrying out work under irradiation is so great it is necessary to eliminate many materials by static and dynamic tests which are easier to carry out, and to reserve the capacity under irradiation for those materials which are acceptable on every other basis. Compatibility may frequently exceed in importance all other physical and mechanical properties. As an example of this, there may be many attractions about a pressurized-water reactor using metallic uranium as a fuel, but the reaction of uranium with pressurized water when they are together is so violent that an alternative and non-reactive fuel must be selected. Similarly, metallic uranium cannot be used as a fuel with hydrogen as a coolant because even should the diffusion of hydrogen through the canning material be reduced to an acceptable amount, the hazard of hydride formation and later decomposition is so great that this could not be tolerated.

Modified Materials

Modification of a material may be possible to ensure compatibility. As an example of this, the compatibility of zirconium with water is increased greatly by the incorporation of some tin to give the zircalloy series. Similarly, niobium is not compatible with carbon dioxide or oxidizing gases, but possibly by the addition of some zirconium or other transition element and by the incorporation of some interstitial element which may affect the oxide coating, compatibility may be achieved. If compatibility is achieved by some metallurgical device of this nature, the effect of irradiation must always be proved. Incorporation of alloying elements may have an important effect on the post-irradiation processing for the extraction of plutonium or recovery of canning material, and this must always be kept in mind.

FABRICATION

The selection of a material on the basis of its chemical, physical or mechanical properties is indefensible if the material cannot be shaped, joined or machined. Far too frequently research laboratories produce a metal of superlative corrosion resistance only to find either that it is too hard to shape or machine, or that it cracks on welding. As an example of this, the earliest magnesium alloy cans for Calder Hall cracked on welding, and this was found to be due to the effect of an unacceptable calcium content in the metal. Tungsten and molybdenum, on compatibility grounds, may show great advantages but there are grave difficulties in shaping these materials and in joining them without cracking. It cannot be sufficiently emphasized that the development of techniques for shaping and joining must proceed colaterally with the development of corrosion-resisting materials. This, as was found with niobium, may lead to extensive metallurgical investigations of the effect of atmospheric contamination and interstage annealing on the constitution and properties of materials.

EFFECT OF REACTOR CONDITIONS

The selection of a material on normal engineering grounds may require to be modified as the result of irradiation conditions. In the construction of the pressure shell for a gas-cooled reactor it has been suggested that once the reactor has been assembled the danger of catastrophic failure from brittle fracture can be avoided if the structure is stress-relieved and the temperature is not allowed to fall below a pre-stated minimum. It has been shown, however, that the temperature range for the transition from ductile to brittle is raised by irradiation by an amount depending on the type and density of the flux and the temperature. Long-term ageing changes which determine the behaviour in creep may also be affected. Even without the effect of irradiation, cyclic changes of temperatures, particularly if phase changes are involved, may produce persistent volume changes and when, as with uranium, the volume change involved in the transition from one phase to another is great, distortion is produced. This is a serious factor in determining the type of fuel and temperature of operation.

Most materials become radioactive after exposure to neutrons. With some materials the half-life of the daughter elements is so long and the emission so hard that a health hazard is presented for a long time. Thus cobalt is a serious contaminant in pressure-vessel steel and its presence will make more difficult any possible maintenance during operation of a reactor. Contamination by elements producing gamma-emitting long half-life daughter elements must be avoided in materials which have to be handled, inspected or maintained during the life of a reactor.

Renseignements Métallurgiques dans la Technique Nucléaire

On y décrit des aspects importants de données physiques, chimiques et métallurgiques dont la signification n'est pas toujours appréciée de l'ingénieur de projetage du réacteur. Les propriétés physiques et mécaniques, la compatibilité, les problèmes de fabrication et les effets de la radiation y sont traités en assez grand détail. La venue et les méthodes d'extraction des matériaux figurent parmi d'autres propriétés considérées lesquelles, bien qu'elles ne soient pas généralement requises par l'ingénieur, pourront servir de guide pour indiquer si ou non un métal convient à une application donnée quant à sa composition ou le point de vue économique représenté. L'importance des diverses propriétés est illustrée principalement de l'expérience acquise à Calder Hall et présente ainsi un intérêt direct à l'égard de la conception des réacteurs refroidis au gaz.

Wissenswertes aus der Metallurgie für den Atomkraft-Ingenieur

Es werden hier wesentliche Gesichtspunkte und Zahlen aus der Physik, Chemie und Metallurgie gebracht, deren Bedeutung vom Konstruktör von Atomkraftwerken nicht immer erkannt wird. Physikalische und mechanische Eigenschaften, die Frage gemeinsamer Verwendbarkeit, Fabrikations-Probleme und die Wirkung von Strahlungen werden mit ziemlichem Eingehen auf Einzelheiten behandelt. Das Vorkommen von Grundstoffen und ihre Gewinnung sind weitere Punkte, die der Betrachtung unterzogen werden, und die, wenn sie auch nicht im allgemeinen vom Ingenieur gebraucht werden, doch einen gewissen Anhalt dafür geben können, ob ein Metall für eine gewisse Verwendung entweder auf Grund seines Aufbaus oder aus wirtschaftlichen Erwägungen heraus geeignet erscheint. Der Wert der verschiedenen Eigenschaften wird in der Hauptsache aus den Erfahrungen beim Bau von Calder Hall hergeleitet, und dies ist auch von direktem Interesse für die Konstruktion von gas-gekühlten Reaktoren.

Información Metalúrgica en la Ingenieria Nuclear

Se describen importantes aspectos de los datos físicos, químicos y metalúrgicos, el significado de los cuales no siempre es apreciado por el ingeniero diseñador de reactores. Las propiedades físicas y mecánicas, la compatibilidad, los problemas de fabricación y los efectos de irradiación son tratados aquí algo detalladamente. La ocurrencia y modo de extracción de materiales están entre las otras propiedades consideradas las que, aunque generalmente no las necesita el ingeniero, pueden servir de guia con respecto a la conveniencia de un metal para una aplicación específica, ya sea por su composición o por motivos de economía. Se ilustra la importancia de las diversas propiedades, mayormente de la experiencia adquirida en Calder Hall, y así es de interés directo en relación al diseño de reactores enfriados por gas.

REMOTE VIEWING

By F. S. BLOXAM

Cells for handling radioactive material, unless fully automatic, must be designed so that operations can be observed by personnel shielded from radiation. Factors affecting the choice of a viewing medium are discussed in this article and recommendations made for the most satisfactory system in given circumstances, bearing in mind the need for standardization and economy.

WORKING with active materials behind a biological shield involves either fully automatic handling or remote manual operation in conjunction with an efficient viewing system.[1] Automation is often uneconomic for many operations and is not sufficiently versatile for research and development work. It follows, then, that the efficiency of the viewing system is usually of the highest importance. While certain operations such as fuel element decanning can be carried out in water tanks, it is intended in this article to confine the field to the viewing of operations carried out in a lead or concrete cell.

Main Requirements

Integrity of viewing free from defects with biological shielding at least equal in effect to the main shield is the primary design aim. A viewing system must allow proper appreciation of depth and colour, a wide angle of vision and the ability to view operations from different positions.

Controlling factor in any viewing system is the effect of radiation on components, including the transparent shielding material, tank lining materials, gaskets, laminated liquids etc. Lighting in shielding enclosures must also be designed with these considerations in mind and allowance made for the decrease in intensity resulting from transmission through optical systems with possible darkening of windows due to radiation.

Glass

Glass is a non-crystalline material produced mainly from inorganic oxides, which can be produced in various forms, including plates and blocks.[2] It is an essential component of all viewing systems and the effect of high-energy radiation on light transmission is one of the most important considerations. A considerable amount of work has been done on the effect of radiation[2, 3, 4] and it can be shown that the loss of light transmission of glass exposed to gamma radiation is affected by:

1. Exposure rate and total exposure.
2. Continuity of exposure.
3. Temperature during and after exposure.
4. The amount of visible light incident on the glass during and after exposure.

The darkening of commercial plate glass exposed to a total dose of 144,000 r in two hours followed by recovery after exposure to normal visible light is shown in Fig. 1. Whilst with similar dosages in daylight, lead/tungsten/phosphate glass shows no appreciable change in transmission, this type of glass cannot be manufactured with sufficient quality to make it a practical proposition for thick windows.

Glasses with good optical properties can, however, be stabilized by the addition of ¼-2% cerium oxide to the melt, but a disadvantage is that with a high lead content and with cerium oxide addition glass has an intrinsic yellow colour. With the very dense (6.2) glasses colour discrimination may become difficult. Fig. 2 shows the light transmission of a stabilized 4.3 density lead glass before and after irradiation.

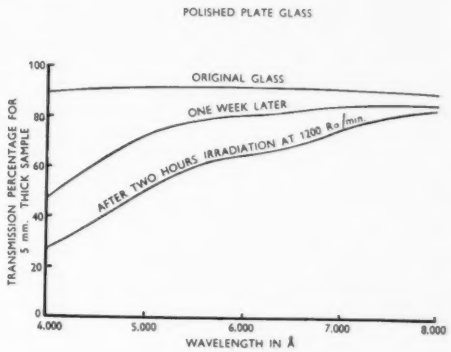


Fig. 1.—(Above) Darkening of glass under radiation.

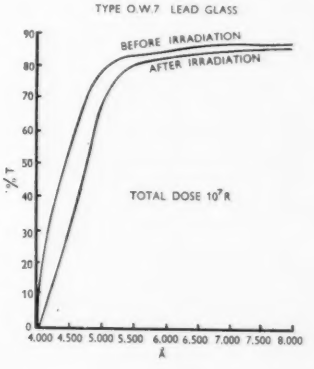


Fig. 2. — (Right) Performance of stabilized glass.

Experience shows that the limit for using unstabilized glass in shielding cells is very low. An active cell handling specimens of the order of 5 c can utilize unstabilized glass, coloration being hardly noticeable after about two years, whilst in a cell handling 100 c sources the glass may start to noticeably colour in a matter of weeks. In this respect the denser the glass the more resistant it is to coloration. A very dense (6.2) unstabilized glass will have a larger working life than a lower density one. Optical glasses such as used in microscope objectives colour relatively rapidly and therefore need to be stabilized unless the working periods are short or activity of samples examined is low.

It is possible to remove the coloration by annealing the glass at a temperature of about 300°C. Intense tungsten light or UV lamps also help to anneal the glass, but whilst

a UV lamp would anneal out the colour from a thin section, such as a lens, the absorbing power of a glass block would be such that the UV energy would not penetrate far enough to anneal more than the surface layers of glass.

Glasses, both stabilized and unstabilized, manufactured in the U.K., that are available for use under active conditions are listed in Tables 1 and 2.

Table 1.—Types of Glass Available for Windows.

Type	Density (g/cc)	Form	Remarks
Pilkington Plate	2.5	Plate up to 1 in. thick	Used on the " cold " side of Zn Br_2 windows or similar position where it is not subject to high radiation dose.
Pilkington Plate Glass (stabilized)	2.5	Plate up to 1 in. thick	Used on the " hot " side of Zn Br_2 windows, as windows or transparent panels where it is subject to high level of radiation.
Pilkington Dense Lead Plate	4.3	Plate 1 in. thick ..	Stabilized or unstabilized, used for laminated glass windows or in " composite " windows.
Chance 700303	4.3	Cast Blocks up to 18 in. × 18 in. × 4 in.	Used as small viewing windows for low activity work.
Chance OW7 (stabilized)	4.3	Cast Blocks up to 18 in. × 18 in. × 4 in.	Used as small viewing windows for medium activity work. Good viewing obtainable through 3 ft thickness (9 blocks).
Chance 927210	6.2	Cast Blocks up to 18 in. × 18 in. × 4 in.	Used as small windows for high activity work.
Chance OW8 (stabilized)	6.2	Cast Blocks up to 18 in. × 18 in. × 4 in.	Used as small viewing windows for high activity work.
Chance Pilkington Blocks	2.5 or 4.3	Up to 4 ft × 3 ft × 6 in.	Built up for large windows.

Systems

The detailed design of any viewing equipment is a function of the activity of the materials to be handled, the manipulative equipment to be installed and the versatility required of the handling facilities. Economic considerations must also be taken into account at an early stage in design, as excessive built-in versatility can disproportionately increase cost.

When practicable, direct viewing through a window is desirable, the transparent material being water, a dense liquid, or glass. Apart from the psychological advantages of directly viewing the operations in hand, the high refractive index of a window (whether liquid or glass) permits a greater angle of vision than would be possible by an open aperture in a thick wall; this angle can approach 180°, but if the operator must have freedom of movement coupled with complete coverage of the interior of the cell, then the window size must approach the size of the working area. Some distortion is inevitable but this is not generally significant.

Colouring in windows can introduce problems and these are best overcome by intelligent lighting, together with complementary methods of viewing. Optical distortion resulting from spherical aberration and faults modifies the resolution, but the advantages of true binocular vision are considerable as a good appreciation of depth is essential for manipulating.

For alpha-active material, viewing is almost unrestricted as all walls can be constructed of transparent material, such as Perspex. For gamma-active work in free-standing handling boxes which are necessarily small, a number of small windows can suffice. In large concrete facilities large single windows up to 5 ft x 3 ft to provide shielding equivalent to 6 ft of concrete are installed.

Windows can be classified under four headings:

1. Small very dense windows (for use in conjunction with lead shielding, tongs and sphere units).
2. Liquid windows (in ordinary concrete walls).
3. Large glass block windows (for dense concrete).
4. Combinations of 2 and 3 (for activities above the limit of liquid windows and to accommodate special cell features).

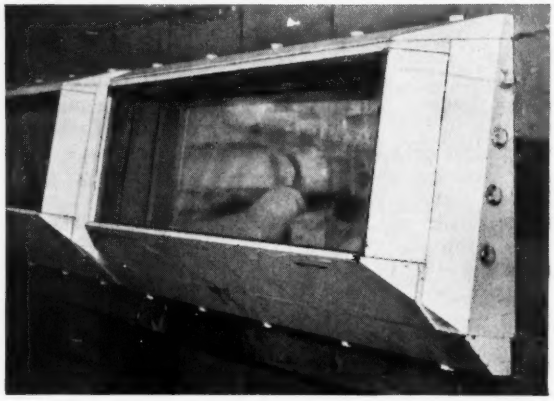


Fig. 3.—Dense lead glass window with additional lead surrounding the projecting portion.

Small Dense Windows

Glass blocks suitable for installation in lead walls are listed in Table 1. Densities available range from 3.9 to 6.2 but it is normal to use as dense a glass as possible to cut down thickness. Over the range of energies normally encountered, shielding power can be taken as proportional to density. At A.E.R.E., Harwell, there has been a move to standardize on 4.3 density glass and 6.2 density glass which are stocked in blocks 6 in. x 6 in. x 4 in., 8 in. x 8 in. x 4 in. and 10 in. x 6 in. x 4 in. These can be built into shielding walls as required and the side faces packed with lead wool. Due to the lower absorption power of glass compared to lead, additional lead shielding is required around the projecting section (Fig. 3). In composite walls (more than one block thick) an air gap of 0.010 in. to 0.015 in. must be left between blocks to avoid interference fringes.

With the denser glass it is necessary to fit glass cover plates (stabilized on the " hot " side) as the surface deteriorates (" blooms ") when exposed to atmosphere. It is important that glass faces are clean, and repolishing, with felt and jewellers' rouge, may be necessary before assembly.

Due to the low light transmission characteristics of the very dense glass it is not practicable to use more than four blocks (16 in.) in depth whilst with the medium density

Table 2.—Glass Suitable for Stabilized Lenses and Instruments.

HC-N-519604 LBC-N-541595 MBC-N-572577 DF-N-620362 EDF-N-700303	Chance Brothers
Fused Silica XU	Thermal Syndicate quality
Pilkington Stabilized Plate (Ri=1.5156 at sodium line)	

glass nine 4-in. blocks can be accommodated without recourse to greatly increased levels of illumination.

Dense Liquid Windows

The most satisfactory liquid medium that has been developed for shielded viewing purposes is zinc bromide, which combines high density (and high atomic number) with excellent light transmission characteristics. There is a slight yellow tinge but transmission at 5890Å is nearly equal to that of pure water (Fig. 4). In order to retain these optical properties great care must be taken with both handling and containment. Liberation of free bromine or contamination, particularly with iron, must be avoided. Oxidation results from exposure to the atmosphere and to radiation but the solution can be stabilized against radiation by the addition of 4oz/100 gal hydrazine hydrobromide. It is advantageous to wait until the solution begins to deteriorate before adding a reducing agent as excess stabilization tends to reduce light transmission. The

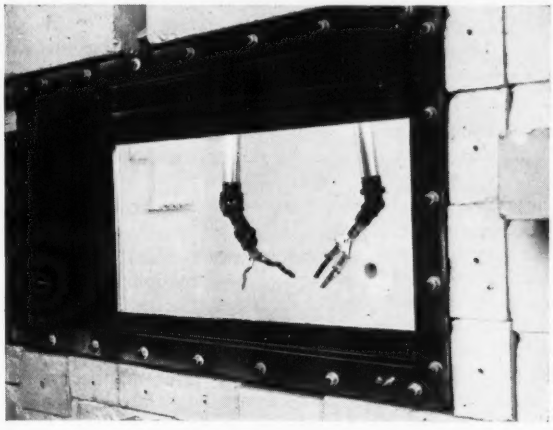


Fig. 4.—5ft zinc bromide viewing tank demonstrating high quality of viewing.

concentration quoted will protect a thin layer from 10^6 r whilst thermal or mechanical stirring for a thick layer (in which little exposure is received by the "cold" side) proportionally increases the tolerable incident dosage.

If the exposure rate exceeds about 5×10^4 r/h oxidation causes bubbling with consequent impairing of vision. An incident radiation of this amount would require zinc bromide shielding 5 ft in thickness; 5 ft therefore representing the maximum useful depth of tank. Further details of the solution are given in Table 3.

Table 3.—Properties of Zinc Bromide Solution.

		Density	R.I.
Refractive Index at 25°C for Sodium Light		2.54	1.552
		2.50	1.559
		2.55	1.565
Electrical Conductivity	1.26×10^4 mho/cm³		
Specific Heat	0.29 cal/g°C		
Cubical coefficient of expansion	0.6×10^{-3}/°C		
Weight $ZnBr_2$ crystals	76%		
Proportions at	2.5 g/cc 24% H_2O		

Containment tanks. The shielding liquid is contained in a tank constructed of either metal or plastic. Foreign materials will impart a strong colour and produce a dense haze in the solution. If a metal container is used the most suitable material is mild steel, as shown in Fig. 5, painted and sealed with "Vybak" 216 as the glass-to-metal gasket.

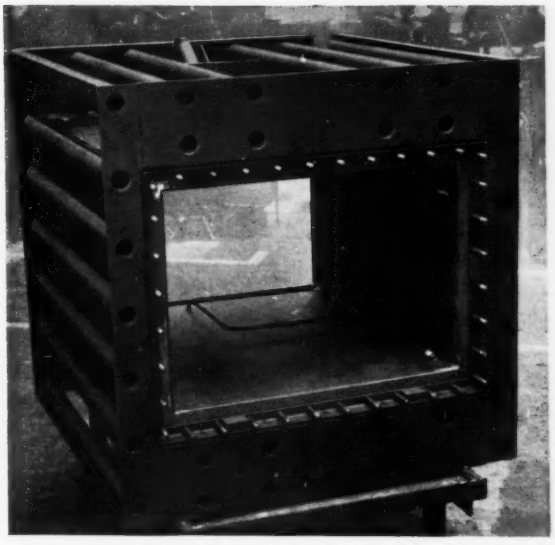


Fig. 5.—A zinc bromide viewing tank under construction for Dounreay. (J. Evans & Son (Portsmouth), Ltd.)

An alternative is a reinforced plastic container constructed of glass fibre-reinforced polyester resin and lined with an epoxide resin. In this type of construction the glass is moulded in position.

Although the plastics will eventually break down under irradiation (approx. 10^9 r) tanks are inexpensive and can be installed so as to be easily removed, either by moulding into the wall or by fitting into a removable concrete surround. The steel tank will be permanent and can be grouted into the wall but periodic repainting and regasketing is necessary (approx. 10^6-10^7 r).

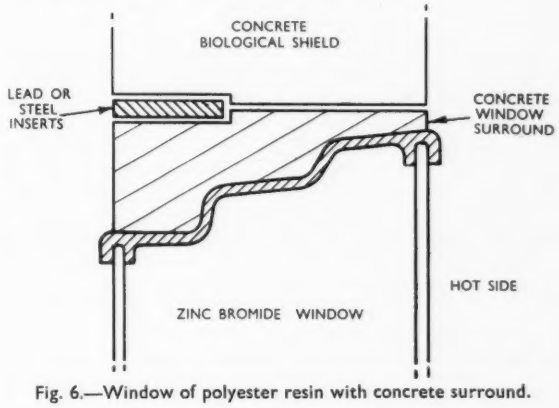


Fig. 6.—Window of polyester resin with concrete surround.

Glass Plates. Annealed plate glass should be employed; stabilized plate on the "hot" side and ordinary commercial plate on the "cold" side. Armour plate glass should not be used as, in the unlikely event of breakage, the whole plate would shatter, thereby suddenly spilling all the $ZnBr_2$ and destroying the shielding effect of the window. In two cases when annealed plate glass was broken during experiments on window strengths the glass merely cracked in several places allowing the liquid to seep slowly out (upwards of 8 hours to empty the window). This type of failure would allow time for active material to be disposed

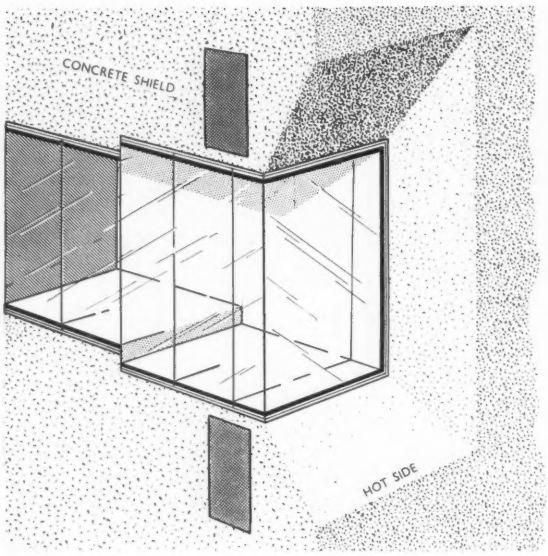
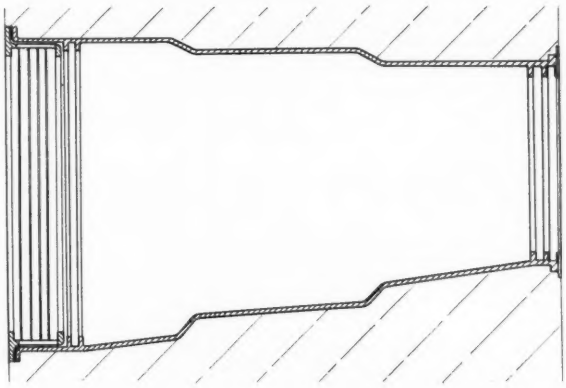


Fig. 7.—(Left) Stepped glass window.

Fig. 8.—(Below) Composite dense glass and zinc bromide window.



of, so that the broken window could be repaired as convenient.

Under working conditions the maximum stress on the glass should not exceed 1,000 p.s.i. Assuming that the ratio length/height is between 1 and 1.5, the stress can be obtained from the equation

$$f=0.29\ W\ ab/t^2$$

where f=stress, W=load at centre of pressure, b=height or minor dimension, a=width and t=thickness.

Glass is normally supplied in a maximum thickness of 1 in. If, for strength reasons, a thicker section is required pieces can be laminated together with an epoxide resin. If this is done the maximum allowable stress should be reduced to about 800 p.s.i. to allow a further factor of safety.

It is important that when positioned in the tank there are no stress concentrations on the glass. With a plastic tank the manufacture is such that the glass will initially be stress free. With a steel construction it is important that the flanges be machined flat and that the glass is not in contact with a hard material; a lead or rubber buffer is placed at the bottom of the plate and gaskets positioned on both sides. Bolts are tightened up carefully using cylinder head techniques and a torque spanner. It is desirable to use a strain gauge in conjunction with fitting the glass to ensure that local over-stressing does not occur.

Large Glass Windows

Due to the different methods of manipulation it is necessary to use large windows when operating through concrete walls. The method of construction is illustrated in Fig. 7. The individual blocks are supplied in their own steel frames and slid into the wall aperture. The blocks are stepped first to prevent "shine" through any gaps and secondly because with the operator stationary the limiting viewing angle is such that a larger area of glass is required on the "hot" side than on the "cold" side. By stepping the window in the manner illustrated this gives a considerable economy of glass.

If a glass of greater density than the main biological shield is used the window can be thinned down thereby allowing either a smaller window to be used or a greater angle of view to be obtained from the same sized window. In this case the biological shield must be reinforced with steel or lead shot around the window in order to prevent shine through the under shielded sections.

Plate glass can be laminated into windows, either by bonding the individual plates together or by fitting the

Examen a Distance

Le travail derrière un écran biologique nécessite l'emploi de l'examen direct par des fenêtres avec ou sans lentilles et des systèmes miroir ou la télévision à circuit fermé. Les fenêtres peuvent consister en réservoirs de solution de bromure de zinc ou en verre d'un fort contenu en plomb qui peut être obtenu en blocs ou en feuilles de grandeur limitée. Il est possible de stabiliser le verre contre l'obscurcissement progressif sous la radiation, et les caractéristiques de différents verres y sont passées en revue.

Fern-Beobachtung

Das Arbeiten hinter einem biologischen Panzer macht es erforderlich, dass Beobachtungen entweder durch Fenster vorgenommen werden, mit oder ohne Linsen- und Spiegel-Systeme, oder mittels Fernsehens im geschlossenen Stromkreis. Als Fenster können Behälter mit einer Brom-Zink Lösung verwendet werden, oder auch Glas mit hohem Blei-Gehalt, das in Blöcken und Scheiben innerhalb gewisser Grössen erhältlich ist. Es ist möglich, Glas gegen fortschreitendes Dunklerwerden infolge von Bestrahlung widerstandsfähig zu machen, und es werden die charakteristischen Eigenschaften verschiedener Glassorten diskutiert.

Visionado a Distancia

El trabajar detrás de una pantalla biológica exige el empleo de visionado directo a través de ventanas, con o sin sistemas de lentes y espejos, o por medio de la Televisión a circuito cerrado. Las ventanas pueden consistir de tanques de solución de bromuro de cinc o de vidrio de elevado contenido de plomo, que se puede obtener en bloques o hojas de tamaño limitado. Es posible establizar el vidrio contra el oscurecimiento progresivo bajo radiación, y se discuten las características de diversos vidrios.

plates into a water-tight tank and filling the spaces with a suitable liquid in order to cut down surface reflection losses.

If the plates are laminated together this should be done with a clear polyester or epoxide resin. These resins will start to visibly discolour at a total dose of approx. 10^7 r and this type of construction should not be used where high radiation levels are expected. The lamination can be treated in a similar manner to the large glass blocks already mentioned. If separate glass plates are used they should be installed in a water-tight tank. These must be stepped in order to prevent shine. The plates must also be spaced and the gaps filled with either Shell (Ondina) 17 oil or paraffin in order to reduce light losses. Provision should be made to replace the laminating liquid should it deteriorate. (Fig. 10.)

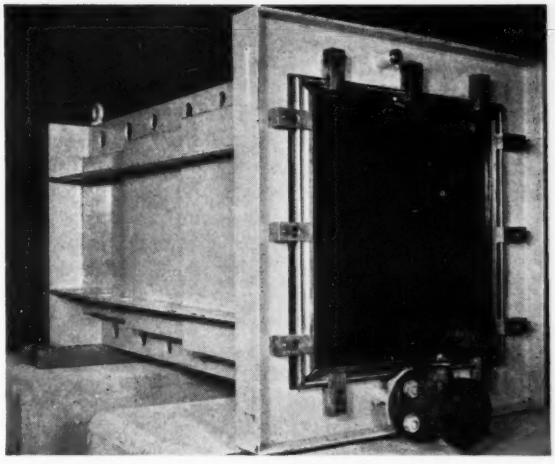


Fig. 10.—Frame for laminated window. Note provision for oil filling.

Composite Windows

For reasons such as obtaining viewing windows of equal thickness as the main biological shield, or in cases where the depth of shielding requires the combination of the high transparency of the zinc bromide solution with the shielding power of the high-density glass, it is possible to build up a composite window using the different viewing mediums. Such a window is illustrated in Fig. 8. It consists of several layers of plate glass on the " hot " side and then $ZnBr_2$.

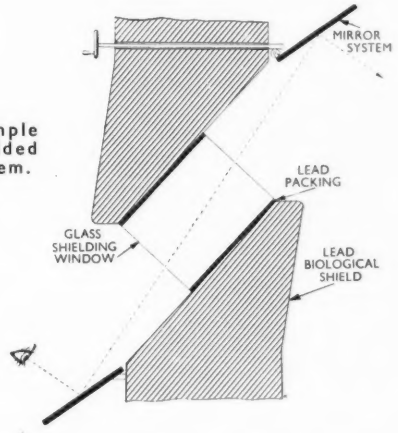


Fig. 9.—A simple indirect shielded viewing system.

Indirect Viewing

Remote viewing can, in the simplest cases, be more convenient and cheaper to install than direct viewing systems and with automatic processes or highly specialized work where a peep hole is the only viewing required an oblique aperture in the shielding with a suitably positioned mirror on the " hot " side may meet operational needs. Alternatively, open-top cells may be viewed through simple periscope systems. With a simple mirror system, however, the image is inverted and with rotating mirrors the orientation of view is altered, and is confusing to any but experienced operators. The apparent distance of the image and therefore the size is a function of the optical path and may be double the direct path.

With open-top cells, and with apertures through shields, radiation scatter is important; and multiple reflecting systems, or combinations of mirror systems and glass blocks, to cut down scatter, may be necessary. (Fig. 9.)

In a plain mirror system, the angular vision is also a function of the optical distance and, because of scatter considerations, the opening in the main shield must be kept small. A static angle of view of 10° can be considered normal and, with scanning systems, a limitation of 60° is imposed by the size of scanning mirror required. Manipulation viewed through a scanning mirror is, however, slow and difficult.

The quality of the viewed image is reduced by the number of reflections and a high standard of mirror surface with front silvering is essential. Appreciation of depth can be obtained by the operator using binoculars but this is valuable only for spot observation.

For detailed examination and for high quality viewing a lens system must be installed. This has the effect of moving the operator's point of view from the eye piece on the " cold " side to the objective on the " hot " side with a consequent improvement in image size and angle of view. It is good practice to limit the length/diameter ratio in a periscope to a maximum of 30 : 1. Normal systems are limited in viewing by aberrations to about 45° and this can be increased by scanning mirrors or prisms.

As with windows, optical glass is subject to discoloration, and provision must be made for the use of cerium oxide-stabilized lenses on the " hot " side. (Front-silvered mirrors are, of course, unaffected.) The range of glasses available, however, is limited (Table 1) and optical systems incorporating stabilized glass are essentially " one-off " productions and, therefore, costly.

With monocular systems depth perception is difficult and simultaneous manipulation is fatiguing with a fixed eye position.

Remote Viewing

Closed-circuit television may be desirable for remote monitoring, but its value in manipulative work is limited, due to its lack of definition and colour discrimination. It is, however, a great asset when a temporary cell has to be set up and brought into operation quickly. For certain routine investigations, such as microscopic examination, it may be more convenient to build into the instrument a television transmitter rather than provide a direct optical path.

Skill at manipulation using television varies considerably

from one operator to another, whilst the value of 3D as opposed to 2D presentation is debatable.

Summary

The ideal method of working is the most natural, that is, the hands are used directly and the working range is no more than about 2 ft 6 in. Due to the necessity of a biological shield this is not possible, therefore all viewing and handling systems must take into account operator inconvenience and be designed accordingly. A compromise must be arrived at whereby the operator has sufficient viewing facilities for him to carry out his function satisfactorily and yet such a system must not be unduly expensive and complicated. It should also be realized that, whilst operations may be limited by practical viewing facilities, the viewing system is usually determined after the operation, method of manipulation and biological shielding material are decided upon.

(a) A zinc bromide window will give the best overall vision. It should be used in conjunction with ordinary concrete shielding up to its limiting activity level.
(b) Above this limiting activity level a composite window of zinc bromide and glass blocks or plates can be used with ordinary concrete shielding.
(c) For the higher levels of activity dense concrete and glass block windows are more suitable.
(d) For lead shielding the very dense glass blocks are appropriate.
(e) For detailed viewing, auxiliary equipment such as periscopes, must be used.
(f) Due to both cost and production problems it is desirable to rationalize designs and sizes.

References

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[2] How to Select and Specify Glass, M. W. Riley, Materials and Methods Manual No. 132, November, 1956.
[3] Coloration of Optical Glass by High Energy Radiation, G. S. Monk, Nucleonics, November, 1952.
[4] A.E.R.E. Report No. C/R 1125, J. V. F. Best.

Reference List of British Reactors

Name	Type	Moderator	Fuel	Coolant	Power and/or Flux (n/cm²-sec)	Purpose	Location	Date operational	Date described in *Nuclear Engineering*	Remarks
GLEEP	Thermal	Graphite	Nat. U	Air	100 kW (3.7×10^{10})	Research	Harwell	15/8/47	May, 1956	First British Reactor.
BEPO	Thermal	Graphite	Nat. U	Air	6.5 MW (2×10^{12})	Research and isotopes	Harwell	5/7/48	April, 1956	
WINDSCALE (2)	Thermal	Graphite	Nat. U	Air		Plutonium	Windscale	1950, '51		
DIDO	Thermal (high flux)	D_2O	Enriched U	D_2O	10 MW (10^{14})	Research	Harwell	1956	Jan., 1957	
PLUTO	Thermal (high flux)	D_2O	Enriched U	D_2O	10 MW (10^{14})	Mat. testing	Harwell	1957		Similar to DIDO except facilities.
ZEUS	Fast		Enriched U	None	100 W	Research	Harwell	Dec., '55	May and Sept., 1956	Critical assembly for Dounreay.
ZEPHYR	Fast		Pu	None	30 W (10^9)	Research	Harwell	Feb., '55	April, 1956	
ZETR	Homogeneous zero energy		Uranyl Sulphate	None		Research	Harwell		April, 1956	Homogeneous zero energy critical facility.
DIMPLE	Thermal	D_2O	Enriched U	D_2O	300 W	Research	Harwell	Aug., '54	Aug., 1956	Versatile zero energy facility.
NERO	Thermal	Graphite		None		Research	Harwell			Zero energy facility.
LIDO	Swimming pool	Water	Enriched U	Water	100 kW (10^{13})	Research	Harwell	Sept., '56	June, 1957	Specifically for shielding measurements
MERLIN	Swimming pool	Water	Enriched U	Water	5 MW (5×10^{13})	Research	A.E.I. Aldermaston	1958	Jan., Feb., 1957	A.E.I. design
MERLIN II	Swimming pool	Water	Enriched U	Water	5 MW (5×10^{13})	Research	A.W.R.E. Aldermaston			Duplicate of MERLIN
DMTR	Thermal (high flux)	D_2O	Enriched U	D_2O	10 MW (10^{14})	Mat. testing	Dounreay (Caithness)		July, 1956	Practically a duplicate of Pluto.
FRED (DOUNREAY)	Fast breeder		Enriched U or Pu	NaK	60 MW heat 15 MW elec.	Experimental	Dounreay	April, 1957	June, 1956	
CALDER HALL (4)	Thermal	Graphite	Nat. U	CO_2	180 MW heat 42 MW elec.	Plutonium and power	Sellafield (Cumberland)	May, '56	Sept. and Dec., 1956	
CHAPEL CROSS (4)	Thermal	Graphite	Nat. U	CO_2	180 MW heat 42 MW elec.	Plutonium and power	Annan (Dumfriesshire)			Duplicate of Calder Hall.
BERKELEY P.S. (C.E.A.) (2)	Thermal	Graphite	Nat. U	CO_2	550 heat 130 elec. *	Power			March, 1957	A.E.I.—J.T. contract
BRADWELL P.S. (C.E.A.) (2)	Thermal	Graphite	Nat. U	CO_2	530 heat 150 elec.*	Power			April, 1957	N.P.P.C. contract
SOUTH OF SCOTLAND P.S. (2)	Thermal	Graphite	Nat. U	CO_2	530 heat 150 elec.*	Power			Feb., 1957	G.E.C., S.-C. contract
HINKLEY POINT P.S.	Thermal	Graphite	Nat. U	CO_2		Power				

*Guaranteed minimum net output per reactor.

Chemical Problems In Coolant Gases

by W. E. DENNIS, B.Sc., D.I.C., Ph.D.
(Chief Metallurgist, The G.E.C./Simon-Carves Atomic Energy Group)

Chemical problems associated with the gas-cooled graphite moderated type of reactor are considered, particularly in respect to the rather complex side reactions that may be expected, and the difficulty of exact estimation of the gas composition that may occur during operation.

IN designing a reactor, considerable care is devoted to ensuring that the materials of construction specified will not react with each other, i.e. that they are chemically compatible. However, with the exception of helium, which suffers from other limitations, all suitable coolants react chemically with some, or all, of the available materials of construction. It is, therefore, necessary to investigate the material-coolant reactions under conditions approaching as closely as possible those which will be encountered in the reactor. The object of the present article is to make a first, and, no doubt, simplified attempt to predict what will be the general nature of the chemical conditions in a CO_2-cooled graphite-moderated reactor.

For the Calder Hall type of reactor the coolant is nominally pure dry CO_2. For this reason, in the early work on the corrosion of materials in this type of reactor[1, 2] most of the tests were carried out in pure CO_2, although in some instances an attempt was made to determine the effect of moisture. In more recent work[3], the effect of the presence of carbon monoxide has been investigated. In future designs, as temperatures are raised and the coolant-material reactions become more important, so the need will grow for simulating reactor conditions more closely in out-of-pile tests. It is, therefore, a matter of some importance to attempt to predict the probable nature of the coolant gas composition under operating conditions and its effect on reactions with materials of construction.

In practice the composition of the gas during operation will be governed by a number of chemical reactions. Among these the more important are:

(1) Reaction between the coolant gas and the graphite moderator according to the equation:

$$CO_2 + C \rightleftharpoons 2CO \quad \ldots\ldots\ldots\ldots\ldots\ldots \text{(I)}$$

(2) Reactions between the coolant gas and metals within the reactor circuit of the type:

$$Mg + CO_2 \rightleftharpoons MgO + CO \quad \ldots\ldots\ldots\ldots \text{(IIa)}$$
$$3Fe + 4CO_2 \rightleftharpoons Fe_3O_4 + CO \quad \ldots\ldots\ldots \text{(IIb)}$$

(3) Reactions between the CO produced in reactions (I) and (II) and moisture from heat exchangers and other sources:

$$CO + H_2O \rightleftharpoons CO_2 + H_2 \quad \ldots\ldots\ldots\ldots\ldots \text{(III)}$$

(4) Reactions between moisture and metals of the type:

$$3Fe + 4H_2O \rightleftharpoons Fe_3O_4 + 4H_2 \quad \ldots\ldots\ldots \text{(IVa)}$$
$$Mg + H_2O \rightleftharpoons MgO + H_2 \quad \ldots\ldots\ldots\ldots \text{(IVb)}$$

Thus the main constituents present in addition to CO_2 will be CO, H_2O and H_2.

The problem of estimating the gas composition would, at first sight, appear to be an impossible one, due to the number of possible gas-metal reactions, each involving a different equilibrium system and rate process. However, it would seem reasonable to assume that reactions (I) and (III) will be rapid in comparison with the gas-metal reactions, which are retarded by the growth of oxide films.

Assumed Conditions

For reaction (I) at a temperature of 330°C and a pressure of 11 atm, in the absence of irradiation, the amount of CO in thermodynamic equilibrium with the CO_2 and graphite would be approximately 0.04% by volume from the data compiled by Kubaschewski and Evans[4]. However, work at Harwell by Nash and Wright would suggest that under irradiation with an outlet temperature of about 300°C a CO concentration of up to 1% may be approached. In the absence of data on the effects of temperature and flux on the equilibrium under irradiation, it is not possible to predict the CO concentration under a given set of conditions. However, for the purpose of the present discussion a value of 1% will be assumed for the types of reactor under consideration. Even if this assumption proves to be incorrect, the reasoning and method of calculation used below will still be applicable, though the quantitative value of the conclusions will be altered. In the case of reaction (III), no data whatsoever on the effects of irradiation are available. For the following discussion it is assumed that the thermal equilibrium is unaltered by irradiation. Again the calculated values may have to be revised when the effects of irradiation are known. In the case of this reaction, however, where all the reacting species are gaseous it would seem likely that the reaction rate will be sufficiently high to ensure that the thermal equilibrium is maintained in the non-irradiated part of the circuit. No estimate has yet been made of the effects of radiolitic dissociation of CO_2 and H_2O molecules on the gas composition in the irradiated parts of the circuit.

Derived Conditions

From the thermodynamic data[5] for reaction (III) it is possible to calculate the values of the equilibrium constant K_3 for various temperatures from the relation

$$\Delta G^\circ_T = -RT \ln K_3$$
$$= \Delta H^\circ_T - T\,\Delta S^\circ_T$$

where ΔG°_T, ΔH°_T and ΔS°_T are the standard free

energy, heat and entropy changes accompanying the reaction. From the relation

$$K_3=\frac{p(H_2)\,.\,p(CO_2)}{p(H_2O)\,.\,p(CO)}$$

it is then possible to calculate the values for the hydrogen to water partial pressure ratios for any particular temperature assuming a CO concentration of 1% by volume. As the partial pressures of hydrogen, water vapour and carbon monoxide to be considered are small compared to pressure of CO_2 the approximation that

$$p(CO_2)\sim P$$

where P is the total pressure in atmospheres, may be used without introducing a serious error.

Thus at 200°C for reaction (III)

$$\Delta G^\circ = -5{,}060 \text{ cal}$$

and hence $K_3=\exp(-\Delta G^\circ/RT)=218$

$$=\frac{p(CO_2)\,.\,p(H_2)}{p(CO)\,.\,p(H_2O)}$$

and as

$$\frac{p(CO_2)}{p(CO)}=\frac{100}{1}$$

$$\frac{p(H_2)}{p(H_2O)}=2.18$$

Table 1 was compiled by this method.

Taking this somewhat oversimplified picture of the gas composition, we may now consider its significance in relation to some practical reactor problems.

Removal of Moisture

It will be noted from the ratios given in Table 1 that, at the lower temperatures, a large proportion of any moisture entering the gas circuit may be reduced to hydrogen. Thus from an engineering viewpoint reaction (III), in the forward direction, is objectionable in that it would render the removal of moisture more difficult. That is to say, the partial pressure of moisture in the gas passing into the dryers would be considerably lower than that which corresponds to the total amount of moisture which has to be removed. The $p(H_2)/p(H_2O)$ ratios are, of course, calculated from thermodynamic data and apply to equilibrium conditions. The extent to which the behaviour of the gas approaches that predicted on this basis will depend upon both reaction rates and transit times.

Table 1.

Temp. °C	$p(H_2)/p(H_2O)$
200	2.18
250	0.92
300	0.44
400	0.15

Problemes Chimiques des Gaz Refrigerants

Le grand nombre de types différents de phénomènes chimiques qui se présentent dans un circuit gazeux tel que le transfert en masse du carbone, l'oxydation des métaux et l'élimination de l'humidité, doivent être considérés en tant qu'éléments constitutifs d'un seul système chimique complexe, plutôt que comme des procédés indépendants. Dans un réacteur modéré au graphite refroidi par de l'acide carbonique, les réactions principales s'effectueront entre le gaz et le graphite, et le gaz et les métaux. En plus, il y aura d'autres réactions principales entre les produits de ces deux, et l'humidité présente, ainsi qu'entre l'humidité et les métaux. Par suite du nombre possible de réactions gaz-métal, le problème de l'évaluation de la composition du gaz à l'opération semblerait être impossible mais on peut raisonnablement supposer que les réactions gaz/métal seront moins rapides (par suite de la formation de pellicules protectrices d'oxyde) que les réactions gaz/graphite ou gaz/humidité.

L'article montre qu'il est possible d'obtenir une évaluation de la composition du gaz bien qu'en l'absence d'autres renseignements sur les effets de l'irradiation sur les réactions chimiques qui ont lieu, elle ne sera que qualitative. Il fait aussi remarquer que des concentrations significatives d'hydrogène pourraient être produites par la réduction de l'eau par de l'oxyde de carbone. Cette réaction empêchera l'accumulation d'hydrogène de sources étrangères, mais pourrait rendre l'élimination de l'humidité plus difficile. L'article montre aussi que la possibilité de formation d'hydrure de zirconium ne peut pas être négligée dans la spécification des conditions d'essai de l'oxydation.

Chemische Probleme bei der Gas-Kühlung

Die vielen verschiedenen Arten chemischer Erscheinungen, die in einem Gas-Umlauf vorkommen, wie z.B. der Massen-Uebergang von Kohlenstoff, die Oxydation von Metallen und die Entfernung von Feuchtigkeit, müssen als Teilerscheinungen eines komplexen chemischen Systems aufgefasst werden und nicht als unabhängige Einzelprozesse. In einem mit Graphit als Brennstoff arbeitenden Reaktor, der mit Kohlensäure gekühlt wird, werden die wichtigsten Reaktionen zwischen Gas und Graphit und Gas und Metallen stattfinden. Ausserdem werden noch weitere Reaktionen zwischen den Produkten dieser beiden Reaktionen und der vorhandenen Feuchtigkeit vorkommen, und schliesslich zwischen der Feuchtigkeit und den Metallen. Infolge der Zahl der möglichen Gas/Metall Reaktionen würde das Problem einer vorhergehenden Abschätzung der Zusammensetzung der Gase unlösbar erscheinen, wenn nicht mit ziemlicher Sicherheit angenommen werden könnte, dass Gas/Metall Reaktionen weniger schnell vor sich gehen (wegen der Bildung einer schützenden Oxyschicht) als Gas/Graphit oder Gas/Feuchtigkeit Reaktionen.

Der Artikel zeigt, dass es möglich ist, die Zusammensetzung des Gases im voraus zu schätzen, obwohl dies wegen des Fehlens jeder weiteren Information über die Wirkungen, die die Strahlung auf die vorkommenden chemischen Reaktionen hat, nur qualitativ sein kann. Es wird weiter dargelegt, dass bedeutende Konzentrationen von Wasserstoff durch die Reduktion von Wasser mit Kohlen-Monoxyd hervorgerufen werden können. Diese Reaktion wird die Ansammlung von Wasserstoff aus äusseren Quellen verhindern, könnte aber die Entfernung von Feuchtigkeit schwieriger gestalten. Der Artikel zeigt weiter, dass die Möglichkeit der Bildung von Zirkonium-Hydrid ausser acht gelassen werden darf, wenn die Prüfungs-Bedingungen für die Oxydation spezifiziert werden.

Los Problemas Quimicos de Gases de Enfriamiento

Los muchos distintos tipos de fenómenos químicos que ocurren en un circuito de gas, tal como la transferencia en masa de carbono, la oxidación de metales y la eliminación de la humedad deben considerarse como componentes de un sistema químico complejo y nó como procedimientos independientes. En un reactor moderado a grafito y enfriado por dióxido carbónico, las reacciones principales serán entre el gas y el grafito, y entre el gas y los metales. Además. habrá reacciones adicionales entre los productos de ambos, y la humedad presente, como así también entre la humedad y los metales. Debido al número de posibles reacciones gas-metal, el problema de calcular la composición de gas en operación parece como si sería imposible, pero puede suponerse razonablemente que las reacciones gas-metal serán menos rápidas (debido a la formación de películas protectoras de óxido) que las reacciones gas-grafito o gas-humedad.

El artículo muestra que es posible hacer un cálculo de la composición de gas aunque, en la ausencia de información adicional sobre los efectos de irradiación sobre las reacciones químicas que ocurren, estos serán cualitativos solamente. También hace resaltar que concentraciones de significación de hidrógeno podrían ser producidas por la reducción de agua con monóxido carbónico. Estas reacciones evitarán la acumulación de hidrógeno de fuentes extrañas, pero puede hacer que la eliminación de humedad se vuelva más difícil. El artículo muestra que la posibilidad de la formación de zirconio hídrico no puede ser descartada en la especificación de las condiciones de ensayos de oxidación.

Accumulation of CO and H_2 from Side Reactions

At first sight, it might appear possible that hydrogen, from oil seals and other sources, together with carbon monoxide, produced in the metal oxidation reactions, might accumulate and eventually reach comparatively large concentrations. However, it can be seen that the following reactions

$$H_2+CO_2 \rightarrow H_2O+CO \quad \ldots\ldots\ldots\ldots (V)$$

$$2CO \rightarrow C+CO_2 \quad \ldots\ldots\ldots\ldots\ldots\ldots (VI)$$

will tend to maintain these species at their equilibrium concentrations. That is to say, hydrogen introduced into the system will be continuously removed as moisture and excess carbon monoxide by carbon deposition.

Fuel Elements

It is necessary to consider the possibility that hydrogen formed by the reaction

$$H_2O+CO \rightarrow H_2+CO_2 \quad \ldots\ldots\ldots\ldots (VII)$$

may diffuse through the can to form uranium hydride by the reaction

$$\tfrac{3}{2}H_2+U \rightarrow UH_3 \quad \ldots\ldots\ldots\ldots\ldots\ldots (VIII)$$

The bulk density of UH_3, which is a fine pyrophoric powder, is only a fraction of that of the uranium from which it is formed. Thus the formation of appreciable amounts of the hydride within a fuel element would result in a burst. It is, therefore, necessary to determine to what level the moisture content must be reduced to ensure that the partial pressure of hydrogen is below that at which uranium hydride would be formed.

It has been shown[6] that the rate of hydrogenation of uranium under one atmosphere of hydrogen reaches a maximum at 250°C. Below this temperature, although the equilibrium is more favourable to hydride formation, the speed of reaction is slow. Above 250°C the formation is retarded by unfavourable equilibrium conditions.[7, 8] From dissociation pressure data,[9] the hydrogen pressures in equilibrium with uranium and uranium hydride have been tabulated for various temperatures in Table 2.

Table 2.

Temp. °C	$p(H_2)$ atm	$p(H_2O)$ atm
200	6.40×10^{-4}	2.95×10^{-4}
250	5.41×10^{-3}	5.93×10^{-3}
300	3.16×10^{-2}	2.66×10^{-1}
400	4.89×10^{-1}	15.22

By substituting the hydrogen pressures in Table 2 into the ratios in Table 1, the partial pressure of water vapour required to produce sufficient hydrogen to convert uranium into hydride can be calculated. These figures are shown in Table 2. It will be observed that at 250°C a moisture content greater than 5.93×10^{-3} atm, which corresponds to 0.054% by volume with a total gas pressure of 11 atm, would be required before UH_3 could be formed. Furthermore, the rate of diffusion of hydrogen through the canning material at these low temperatures should be extremely low even under irradiation.

Table 3.

Temp. °C	$p(H_2)$ atm	$p(H_2O)$ atm
200	1.71×10^{-13}	7.83×10^{-14}
250	1.45×10^{-11}	1.59×10^{-11}
300	7.29×10^{-10}	1.66×10^{-9}
400	2.56×10^{-7}	1.71×10^{-6}

The Can

In carrying out oxidation tests the effects of the presence of small partial pressures of hydrogen may have to be considered with metals which form stable hydrides. For example, in the case of zirconium Gulbransen and Andrew[10] propose the equation:

$$\Delta G^\circ = -34,930-2.25\ T\ \ln T+43.88\ T$$

for the standard free energy change of the reaction

$$Zr+\tfrac{3}{4}H_2 \rightleftharpoons Zr\,H_{1.5} \quad \ldots\ldots\ldots\ldots\ldots (IX)$$

This is obtained using an estimated, approximate value of ΔCp for the reaction and applies to $Zr\,H_{1.5}$ in equilibrium with the α-zirconium phase at the appropriate temperature.

The dissociation pressure of zirconium hydride can be calculated using the relationships

$$\Delta G^\circ_T = -RT\ \ln K_T$$

and

$$K_T = \frac{1}{p(H_2)^{\frac{3}{4}}}$$

where K_T is the equilibrium constant for reaction (IX) at the required temperature and $p(H_2)$ is the dissociation pressure of $Zr\,H_{1.5}$ i.e. the hydrogen pressure in atmospheres in equilibrium with α-zirconium and pure $Zr\,H_{1.5}$.

It can be seen that the water vapour content cannot reasonably be kept below the values in Table 3 and consequently at all temperatures there is theoretically a possibility of hydride formation. From the work of Gulbransen and Andrew[10, 11] the rate of reaction may be rapid. It should be noted, however, that formation of an oxide film may retard the hydriding.

Conclusions

(1) Processes involving the coolant gas such as the mass transfer of carbon, the oxidation of metals and the removal of moisture should not be viewed as isolated and independent phenomena.

(2) In the absence of further information on the effects of irradiation on chemical reactions occurring in the gas circuit only a qualitative picture can be obtained of the gas compositions likely to be established during operation.

(3) Under what appear to be likely conditions in a CO_2 cooled graphite moderated reactor it may be shown that significant concentrations of hydrogen might be produced by the reduction of H_2O with CO.

(4) The water-gas reaction will prevent the accumulation of hydrogen from extraneous sources but may render the removal of moisture more difficult.

(5) In the presence of very small concentrations of water vapour the formation of zirconium hydride is thermodynamically possible at all temperatures and cannot, therefore, be neglected in specifying conditions for oxidation tests.

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Boiler Circulation Research

Work in progress at Cambridge University, in collaboration with the Water Tube Boilermakers' Association, on pressure drops and flow conditions of steam/water mixtures in tubes is expected to be of considerable assistance on the design of high-pressure boilers and of heat exchangers in general. This article surveys the background of the subject and the methods employed.

ONE of the most important items in heat transfer calculations is, of course, a thorough knowledge of the properties of the fluid involved. The present research is aimed at establishing experimental information on the pressure drop and flow conditions of a steam/water mixture flowing along heated and unheated tubes at pressures up to the critical (3,206 p.s.i.).

Background

In 1949, theoretical studies were being made at Cambridge University by R. W. Haywood, University Lecturer in the Department of Engineering, regarding the rate of circulation in a simple boiler circuit; resulting in the rationalization of the existing, but previously conflicting theories known as the "hydraulic," "thermo-dynamic," and "expansion" theories of circulation. Results were published in a paper[1] which was deliberately confined to a study of circulation theories which were based on the assumption that the steam/water mixture moved as a homogeneous fluid. The assumption is known to be questionable, but its use is usually justified by the resulting simplification in a theoretical approach to the problem of circulation.

Attention was drawn to the limitations of the experimental work undertaken at Cambridge, which was confined to a simple U-circuit at atmospheric pressure, without steam production in the riser. It was not, therefore, possible to study the effect of relative velocity between the steam and water phases of a steam/water mixture, commonly called "bubble slip," which is known to exist under actual flow conditions in a boiler circuit.

It was, therefore, agreed that further research should be carried out by the University under a research contract with the Water Tube Boilermakers' Association for fundamental work on this problem over a wide range of industrial pressures and new equipment has been erected on the site of a disused aircraft factory on the outskirts of Cambridge.

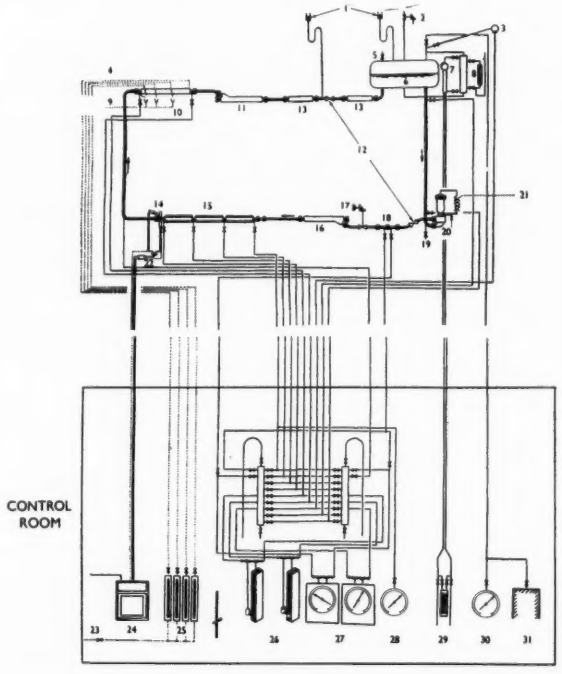
Method of Carrying Out Tests

Basically the test rig consists of a closed-loop system with forced circulation so that velocity is independent of heat input. Water is heated to saturation temperature before it enters the test section proper. The test section can be arranged horizontally, vertically, or at an angle, if required, and is heated by means of low-frequency induction heating which gives the dual advantage of being easily measured and of not interfering in any way with the flow.

Measurements are made to determine the effect of several variables, including pressure; heat input rate; internal diameter and inclination of test section; the velocity of the water entering the heated test section; and the dryness fraction of the emergent steam/water mixture.

The test section is 24 feet in length, but the heaters have been designed to permit heating over 8, 16 or 24 feet as desired. By this means the pressure drop in the unheated pipe following the heated part of the test section can be measured at selected inclinations. The rate of circulation is measured by a standard orifice assembly, and regulated by a control valve.

An immersion-type preheater is used to ensure that the fluid enters the inlet of the heated test section at exactly the saturation temperature corresponding to its pressure at that point; thus offsetting heat losses in the pump and connecting pipework and the effect of pressure difference between the test section inlet and the steam drum. Accuracy



Key diagram of plant.

1 Rupture discs. 2 Emergency blow-off and air vent. 3 Constant head chamber. 4 Condenser cooling water. 5 Filling connection. 6 Steam and water drum. 7 Constant head chamber and water bottle for remote liquid level indicator. 8 Gauge glass (low pressure) for filling only. 9 Discharge to drain. 10 Calorimeter condenser. 11 Reheater (hand controlled). 12 Emergency valve (automatic closure). 13 Drum heater—(hand/automatic control). 14 Gamma ray device. 15 Induction heaters surrounding test section. 16 Preheater (hand controlled). 17 Flow control valve (operated from control room). 18 Metering orifice. 19 Blowdown valve. 20 Electromer.ible pump 60 ft. head: 53 g.p.m. 21 Cooling water (town supply). 22 Head amplifier. 23 Cooling water (town main). 24 Vibrating reed electrometer and recording unit. 25 Flowmeters (cooling water). 26 Differential pressure manometers. 27 Differential pressure gauges. 28 Pressure gauge (inlet to test section). 29 Remote liquid level indicator. 30 Pressure gauge (drum). 31 Automatic pressure control.

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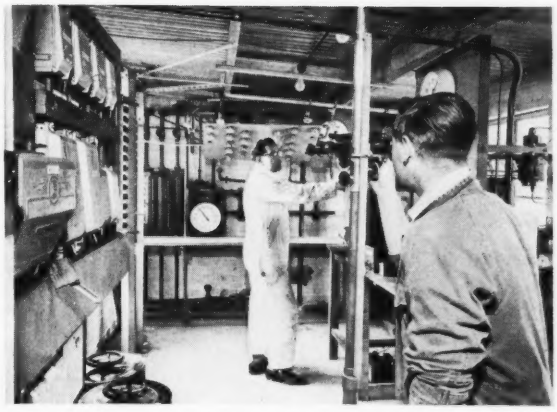
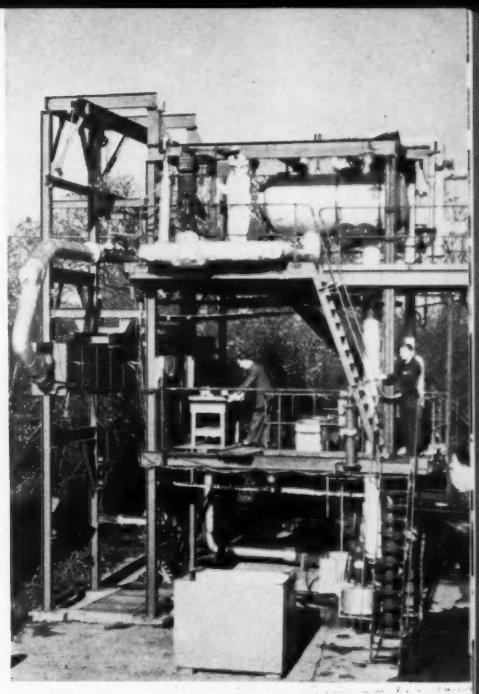


(Left) View of control room



(Right) General view of plant.

is achieved by measuring the differential pressure between the test section inlet and the drum, and then adjusting the differential temperature—which is measured directly by calibrated thermocouples—to correspond to this pressure difference. Consequently, steam generation commences exactly at the inlet and takes place along the entire heated length of the test section. When desired, only the first 8 or 16 feet of the test section need be heated, so that both evaporating and non-evaporating conditions can be investigated.

At the test section outlet is connected a short length of alloy-steel tube, the contents of which are scanned by a gamma-ray beam. An ionization chamber at the opposite end of the diametral axis acts as a receiver, and measures the emergent radiation, which is a function of the density of the water/steam mixture. On leaving the test section the steam/water mixture enters a condenser and finally passes through a reheater before returning to the drum. Constancy of the operating pressure is maintained by combined adjustment of the quantity of condenser cooling water and the electrical input to the reheater.

Complete automatic control of the circuit is not intended, and the initial tests have been regulated entirely by manual adjustment.

Induction Heating

Very little information was available on this type of low-frequency induction heating and much preliminary work—itself in the nature of a fundamental investigation—had to be done to establish what heat input rates were possible. The results of this investigation are expected to be of value in other applications in addition to having a direct bearing on the present research. The heaters were designed and constructed in the Engineering Department of the University in consultation with Wild-Barfield Ltd., who hold a patent on a certain feature of the water-cooled windings. The design finally adopted permits the power supplied to be varied over a considerable range in a number of steps without the use of a large and expensive voltage regulator.

The inductors for heating the test section are made up of series-parallel groups of water-cooled coils of copper tubing. The coils, each having $11\frac{5}{6}$ turns are connected in series to form sections of 17 coils, six of these sections forming a unit, approximately 4 ft long, there being six units along the 24-ft length of the test section of tube. Busbars along the length of the test section allow for series-parallel grouping of the units as required.

The test section tube itself is copper-sprayed to a thickness of 0.05 in., to increase its conductivity.

Thermocouple Design

In this work it is most important to measure accurately the difference between the temperature of the water at the test section inlet and that in the drum, so that the water enters the test section as close as possible to its saturation temperature.

It was eventually decided to measure this temperature difference directly by two thermocouples connected differentially, so that the wires of each thermocouple must be electrically insulated from the sheath in which they are carried. This arrangement introduced difficulties which had to be solved before a design capable of withstanding the pressure, yet of sufficient accuracy and sensitivity, was obtained. In the final design the couples were made from chromel-constantan wire since it gave the highest e.m.f. for any specified level of temperature, the wires being continuous from hot junction to cold junction. High sensitivity was obtained by making the extremity of the sheath of thin-walled stainless steel tubing and it is consequently believed that the temperature difference recorded by these couples will be reliable to approximately $\frac{1}{2}$°F over the range encountered.

A further interesting development is the use of triple-junction differential thermocouples to measure the temperature rise of the cooling water flowing through the coils of the induction heating units.

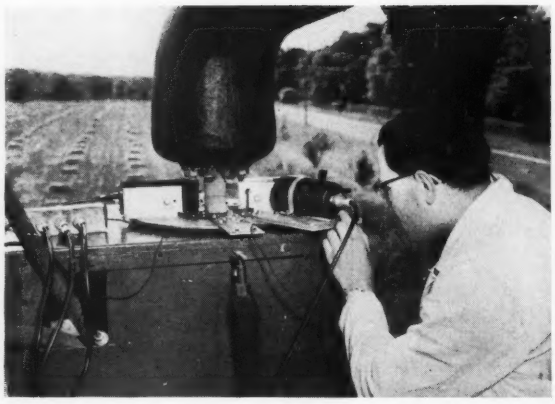
Density Measurement

This equipment, which has been supplied on loan by the Atomic Energy Research Establishment, Harwell, enables an estimate to be made of the apparent density of the fluid mixture leaving the test section, and consequently the respective velocities of the two phases at that point.

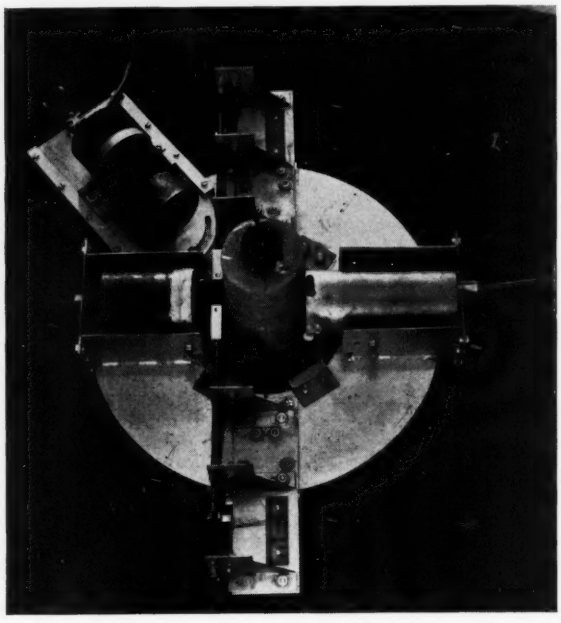
It consists of a gamma-ray source and ionization chamber on opposite sides of a length of high-tensile steel tubing which forms part of the water circuit. The use of alloy steel reduces the wall thickness at this point and gives increased sensitivity.

Originally the source consisted of a 1×1 mm capsule of Iridium 192, having a strength, when new, of about 40 mc, and a half-life of only 70 days, but this has now been replaced by a 2×2 mm source of Caesium 137 of similar strength, but with a half-life of 33 years.

For convenience and safety it is desirable to use a weak



(Left) Gamma-ray density measuring head in position. (Below) Another view of the equipment.



source, and the sensitive ionization chamber and high-magnification electrometer enable this to be done. However, to improve even further on the sensitivity of the device, a secondary or " backing-off " ionization chamber is fitted. The use of this chamber indirectly enables the very small changes in the ionizing current resulting from changes in the density of the fluid to be magnified and more easily measured.

The measurements obtained from the use of this equipment, together with a knowledge of the flow rate and heat input in the test section, enable the respective velocities of the steam and water phases at the scanning point to be estimated. The velocities thus calculated are " average " values, and provide means of estimating the respective pressure drops due to acceleration and wall friction. In addition a knowledge of the mean density is particularly valuable when the test section is in the vertical position.

It has been agreed that two more of these devices should be mounted on the vertical test section at the 8 ft and 16 ft levels. The adoption of this proposal will enable the build-up of " slip," which is expected to be more marked in the vertical position, to be carefully studied.

Progress

Preliminary trials were carried out with a test section of one-inch bore, 24 feet long, mounted in the horizontal position. These were planned mainly to enable the operating staff to become familiar with the response of the respective controls, and to check the accuracy of the various measuring and recording instruments. A further series was subsequently conducted at four pressure levels, and the results carefully analysed. Proposals were made for improving the operation of the experimental plant—by effecting certain refinements to the equipment and operating technique—and these were accepted by members of the Technical Advisory Panel. It had been agreed earlier that the operating technique should be perfected with the test section in the horizontal position since the gravitational effects in a vertical pipe were expected to render the analysis more difficult.

The first full series of tests was then effected on the one-inch bore horizontal test section at five pressure levels, 250, 600, 1,250, 2,100 and 3,000 p.s.i. The results of these tests, together with those obtained from other tube sizes at various inclinations, will be published in due course.

Recherches sur la Circulation des Chaudières

La circulation de l'eau dans les tubes de chaudières à des pressions élevées est un sujet complexe et la plupart des théories sont basées sur la supposition que le mélange vapeur/eau dans un tube de chaudière se comporte comme un fluide homogène; une théorie convenable, mais qui prête à des objections. Quelques recherches à ce sujet ont été effectuées à l'Université de Cambridge avant 1951 et ont été étendues pour couvrir des pressions plus élevées, le projet étant sous le parrainage de la Water-Tube Boiler-Makers Association. Une série complète d'essais a été effectuée sur des tubes horizontaux de 2,54 cm de diamètre à des pressions allant jusqu'à environ 210 kg/cm², et d'autres essais sur des grandeurs de tubes différentes sont en train d'être effectués. La densité apparente du mélange vapeur/eau est mesurée par des rayons γ obtenus d'une source caesium.

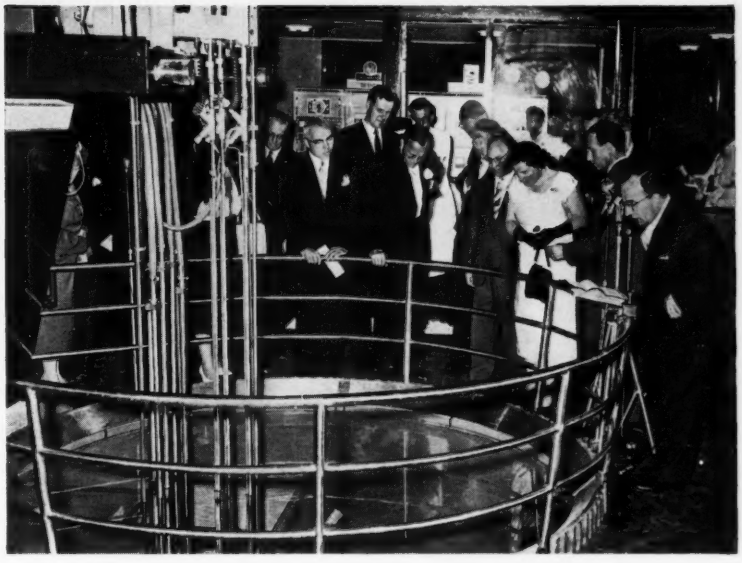
Forschung über den Umlauf in Kesseln

Der Umlauf des Wassers in den Rohren von Kesseln, die unter hohem Druck arbeiten, ist ein verwickeltes Thema, und die meisten Theorien sind auf der Annahme aufgebaut, dass die Mischung von Dampf und Wasser im Kesselrohr sich benimmt wie eine homogene Flüssigkeit; eine sehr bequeme Theorie, jedoch recht fraglich. Man ist diesem Forschungsproblem an der Universität Cambridge vor 1951 nachgegangen, und die Arbeiten sind dann ausgedehnt worden, um auch höhere Drücke zu umfassen, ein Projekt, an dem die Vereinigung der Wasserrohr-Kessel-Fabrikanten Interesse genommen hat. Eine ganze Serie von Prüfungen ist an einem waagerechten Rohr von 2,54 cm Durchmesser unter Drücken bis zu ungefähr 210 kg/cm² durchgeführt worden, weitere Prüfungen von Rohren von verschiedenen Grössen und in verschiedenen Neigungslagen sind in Vorbereitung. Die anscheinende Dichte der Dampf-Wasser-Mischung wird mit γ-Strahlen gemessen, die von einer Caesium-Quelle ausgehen.

Investigaciones Sobre la Circulación de Agua en Calderas

La circulación de agua en tubos de calderas a altas presiones es un asunto complejo y la mayoría de las teorías están basadas sobre la presunción de que la mezcla de vaporagua en un tubo de caldera se comporta como un fluído homogéneo; una teoría conveniente, pero discutible. Algunas investigaciones sobre este asunto se han llevado a cabo en la Universidad de Cambridge antes de 1951 y éstas se han hecho extensivas para abarcar presiones más altas, el proyecto habiendo sido respaldado por la Asociación de Fabricantes de Tubos de Agua de Calderas. Se ha llevado una completa serie de ensayos en un tubo horizontal de 2,54 cm. de diámetro a presiones hasta aproximadamente 210 Kg/cm², y se hallan en progreso ensayos adicionales sobre tubos de diferentes tamaños e inclinaciones. La aparente densidad de la mezcla de vapor-agua se mide por rayos y obtenidos de una fuente de caesio.

Nuclear Energy in Holland



(Above left) H.R.H. Prince Bernhard of the Netherlands performing the opening ceremony at "Het Atoom." (Above) H.M. The Queen of the Netherlands and Prince Bernhard examining the swimming-pool reactor.

THE opening of the "Het Atoom" exhibition on June 29 could hardly be described as the entry of the Netherlands into the nuclear field. Holland, in fact, was very early abroad in that field, a considerable amount of research work having been carried out while she was still an occupied country.

"Het Atoom," however, does represent the first step towards the spread of popular information on nuclear matters within her own boundaries. It is, in fact, an exhibition for her own people, to interest them in the prospects and possibilities of nuclear energy.

In order to obtain an idea of the state of the art in the Netherlands it is necessary to look back to 1946 when the F.O.M. or Foundation for Fundamental Research on Matter was formed with the object of co-ordinating nuclear research both inside and outside the universities. By this means it was hoped to restore Netherlands' prestige in the shortest possible time. The handicaps of the war and occupation had, however, caused so much backlog in this direction that it was soon realized that the Netherlands would not, by itself, be able to make up this backlog and the F.O.M. began discussions with Norwegian organizations with a view to the pooling of resources in a joint effort to construct a heavy water reactor (Jeep), the Dutch contributing a quantity of uranium obtained before the war. The relationship between Norway and the Netherlands was first formally established by contract in 1951, when international co-operation for peaceful purposes was still a novel idea. In 1955 the contract was revised when the F.O.M. organization handed over its part of the contract to the newly-formed R.C.N.

Present Organizations

The following organizations exist at present:

GOVERNMENT INSTITUTIONS

The Co-ordinating Commission for Atomic Energy set up in 1955 composed of representatives of the Ministries of Foreign Affairs; Finance; Economic Affairs; Education, Arts and Sciences. Duties of the Commission include acting as advisers to the Government on the peaceful uses of atomic energy and to instruct the Government representatives on the Managing Committee of R.C.N. It has various sub-committees dealing with legislation, foreign affairs, security, selection of sites, insurance, etc.

The Bureau for Atomic Affairs set up in 1956 as a sub-division of the International Organizations department of the Ministry of Foreign Affairs.

The Nuclear Energy Department under the Directorate-General of Industrialization and Power Supply in the Ministry of Economic Affairs.

OTHER INSTITUTIONS

R.C.N. (Reactor Centrum Nederland) or Institute for the Development of Nuclear Science for Peaceful Purposes.

In this, the Government, Science (represented by F.O.M.), electricity producers and industry are equally represented. The object of R.C.N. is to acquire scientific knowledge and experience in the nuclear reactor field and to make it available to Netherlands institutions and enterprises. It is expected that the staff will comprise some 300 (including 60 university graduates) by 1960.

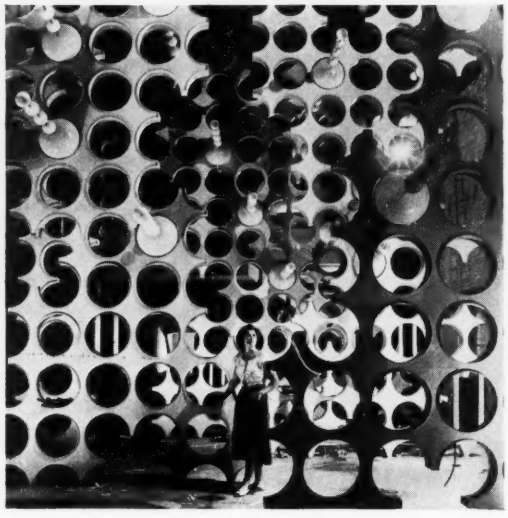
F.O.M. (Fundamenteel Onderzoek der Materie) or Foundation for Fundamental Research on Matter.

This is headed by a group of professors of physics. It was founded in 1946 with the object of co-ordinating nuclear research both inside and outside the universities to restore Netherlands prestige in this field within the shortest possible time. The Reactor Committee ceased to exist on the formation of R.C.N. As may be implied from its title, F.O.M. is interested in pure science, and it has four working parties (comprising 22 teams) active in the fields of nuclear physics; mass spectroscopy; metals; molecular physics. A study group was formed in October, 1956, to work on nuclear fusion, and research is also being carried out for the R.C.N. into the possibility of isotope separation by means of an ultra-centrifuge.

The I.K.O. (Instituut voor Kernphysisch Onderzoek) or Institute for Nuclear Physics Research.

The I.K.O. which has its headquarters in Amsterdam itself can be regarded in some ways as a special working party of the F.O.M. Its organization is a little

(Left) Handling isotopes produced in the cyclotron at I.K.O. (Below) A large display unit in the isotope section at "Het Atoom."



complex since the cyclotron (around which the Institute may almost be said to have been built) is the property of the Philips organization who own and maintain it, and the buildings were provided by the City of Amsterdam.

The cyclotron, a 50 MeV unit, has an interesting history in that many of the parts were secretly built in the Philips works before the end of the war, while the factory was actually in German hands.

Three groups, specializing in β-spectroscopy, radiochemistry, and cyclotron work are housed at the I.K.O.; there is also a small Philips group engaged in the production of isotopes.

Koninklijk Instituut van Ingenieurs (Royal Institution of Engineers) **Nuclear Energy Division.**

This Division has been established to study, in conjunction with the Royal Netherlands Chemical Society and the Netherlands Physical Society, technical problems of nuclear energy such as metallurgical and heat exchange problems; production and application of isotopes; health protection and safety measures.

Marine Propulsion Study Group

Although propulsion of vehicles and vessels falls within the terms of reference of the last-named organization, the main body for the study of marine propulsion is a group set up in October, 1956, under the auspices of the R.C.N. by a group of shipping and shipbuilding companies, engineering companies, and the T.N.O. or Central Netherlands Organization for Applied Scientific Research. The engineering companies represented include "Werkspoor" of Amsterdam and the Stork N.V. of Hengelo, the latter, of course, being a Babcock and Wilcox associated company.

Working Team of the Netherlands Electric Power Industries

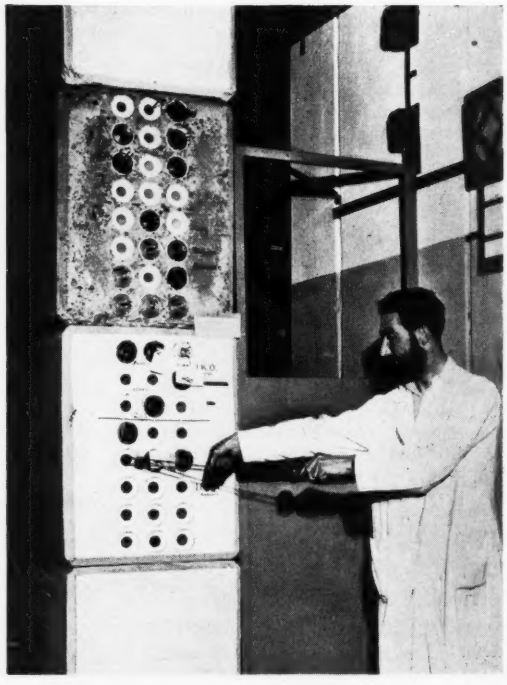
A committee has been set up by the electric power industries to make comparative studies of the technical and economic merits of power reactors manufactured overseas. Experience gained in construction and operation of reactors purchased abroad will also be made available to the R.C.N. unless the interests of third parties are affected.

Isotope Committee of the Royal Netherlands Academy of Sciences. This Committee was originally set up in 1947 as the competent authority to assume responsibility for isotopes purchased from the U.S.A.E.C. It has also acted as advisor to the Government in framing regulations for safety in the use of isotopes.

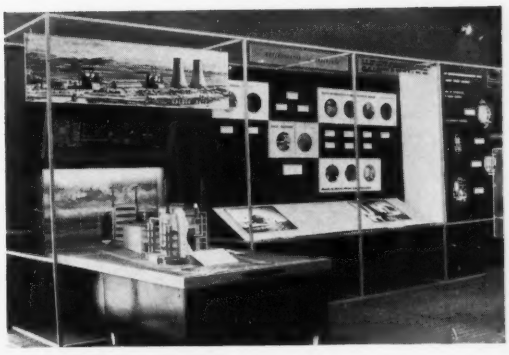
There are also several organizations dealing with measurements of radioactivity.

"HET ATOOM"

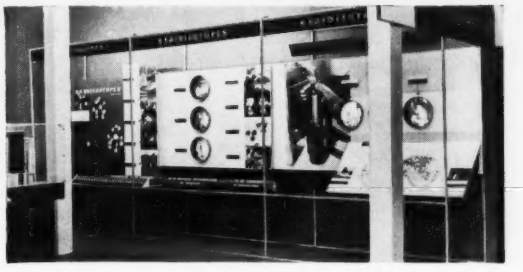
As has been previously emphasized this exhibition is neither a scientific exhibition nor a trade fair, it is intended to tell the story of nuclear energy to the man in



Shielded housing for targets at the entrance to the working area of the I.K.O. cyclotron.



(Right and below) Portions of the British exhibit staged by the Board of Trade and the Atomic Energy Authority.



(Right) H.M. The Queen of the Netherlands making the opening tour of "Het Atoom."

the street; to acquaint him with the prospects and possibilities of nuclear energy, and it tells the story simply and well. Commencing with primitive man, it proceeds to early sources of power, the windmill, the watermill, early steam and internal combustion engines and gradually leads up to power from the atom.

The most impressive single exhibit is, of course, the A.M.F. swimming-pool reactor which is, later, to find its permanent home in the University of Delft. Other reactors are shown as scale models, with the exception of the Brookhaven reactor which was shown as a full size mock-up of the operating face.

Other interesting exhibits were replicas of the workshop of the Curies and of the worktable of Otto Hahn, both shown in a series which included an alchemist's paraphernalia. Of the many working displays, one particularly noteworthy was an animated model of an atom in which the nucleus was represented by clusters of stationary lamps and the electrons by single lamps rotating at the ends of thin wires. This model, by interlocked switching, could be made to represent different elements; in each case the correct number of protons and neutrons lit up in the nucleus while the number of electrons and the orbital spins changed to correspond.

The exhibition included an international section with stands illustrating the development of nuclear energy in Great Britain, France, Belgium, Norway and the U.S.A.

Britain's Participation

Britain's achievements in the nuclear field are shown by an exhibit staged by the Atomic Energy Authority in conjunction with the Board of Trade, and includes models of Calder Hall. A model of the South of Scotland power station is shown by the General Electric Co., Ltd.

Other British companies were represented in a number of the exhibits. Considerable interest was added to the working reactor by the incorporation of underwater television by Pye Ltd., of Cambridge, so that spectators on the exhibition floor could observe the core on monitor screens and see the "blue glow" and the movements of the control rods.

Baldwin Instruments, Ltd., were showing their thickness gauge and an exhibit showing the irradiation of plastics was jointly arranged by Imperial Chemical Industries, Ltd., and Tube Investments, Ltd. Manipulators were shown by Western Detail Manufacturers, Ltd., of Bristol, and by Pye, Ltd., of Cambridge, while Chance Pilkington lead glass blocks were featured in conjunction with shielding in a "hot" laboratory unit. Townson and Mercer, Ltd., of Croydon, were also represented.

Reactor Programme

The present programme for the joint Netherlands-Norwegian establishment covers two research reactors and two power reactors, i.e.—

1. JEEP (a Joint Establishment Experimental Pile at Kjeller, Norway). This went critical in 1952.
2. A high flux research reactor in Holland at Petten on the North Sea coast. This will be in operation in 1958.
3. A steam-producing reactor at Halden in Norway, natural uranium fuelled and heavy water moderated. It is hoped that experience with this reactor will form the basis of a ship propulsion reactor.
4. SUSPOP at Arnhem. This design utilizes pelletized uranium oxide as a slurry in suspension, hence its name, and is being developed by K.E.M.A. The experimental unit, now under construction, is rated at 250 kW, the next step will be a unit of 10-30 MW thermal output. A dry-type suspension design is also reported to be in an advanced stage.
5. A swimming-pool research reactor which is already in operation at Schipol as part of "Het Atoom" exhibition, and will later be transferred to the reactor school at Delft University. In its present temporary pool at the Exhibition it is operating at up to 10 kW but the power level will be raised to 100 kW when it is accommodated in its permanent tank.

Power Reactors

At the time of going to press the equivalent of a Parliamentary White Paper has just been presented by Professor Dr. J. Zijlstra, Minister of Economic Affairs. It points out that by 1975 only one-third of Holland's requirements of energy can be produced in the form of coal. The plan envisages a series of nuclear stations commencing in 1962 with some 1.4% of her energy requirements produced from nuclear sources, this percentage rising to 50% by 1975. The plan is not by any means cut and dried; it is not stated, for example, what types of reactors or how many are to be built.

There seems to be good reason to believe, however, that the first station will be of the gas-cooled graphite moderated type, of a capacity of some 150 MW in the province of North-Brabant, the estimated cost being 180-200 million guilders (£17-19 million).

The APPR —

Some Problems and Their Solution

IN the July, 1956, issue of *Nuclear Engineering* a brief description was given of the Army Package Power reactor, then in course of construction by Alco Products Inc.* Kenneth Kasschau, manager of Alco's atomic engineering division, has recently read a paper before the A.S.M.E. which reviews some of the problems that had to be faced in design and construction.

General Design

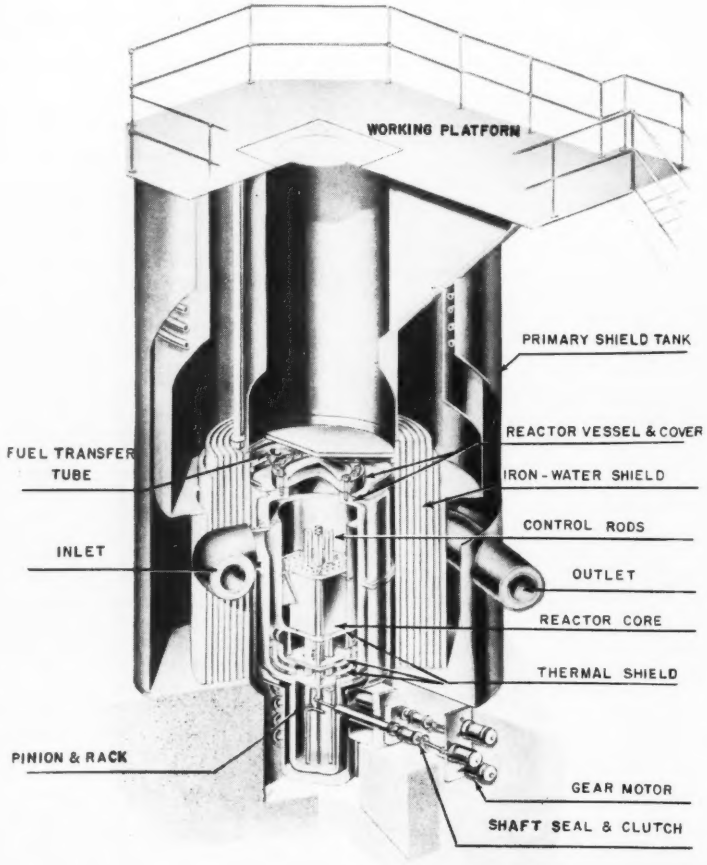
It may be worth while briefly to summarize the main features of the APPR, which was designed on the principle that no part of the equipment should be larger than a container 7 ft square × 18 ft long or weigh more than 10 tons so that it would be possible to fly a complete power station—and fuel for its estimated lifetime—into an out-of-the-way location. Located at Fort Belvoir, Virginia, near the Potomac River, it has an electrical output of some 2.1 MW gross (1.9 net). The core is approximately 20 in. square by 22 in. high, and consists of 38 fuel rods and seven control rod assemblies.

Highly-enriched uranium dioxide fuel is incorporated into plate-type elements, each assembly consisting of 18 fuel plates brazed into a pair of stainless-steel side plates 27 in. long, 2.863 in. wide and .050 in. thick, the internal plates being 23 in. long.

The control rods consist of a fuel section, and an absorber section. Control-rod fuel plates are fabricated in the same manner as the stationary fuel plates, but are 23 in. long, 2.56 in. wide, and .03 in. thick. The absorber section is boron enriched.

Water, forming the coolant and moderator enters at 431° F and leaves at 450°F, the operating pressure being 1200 p.s.i. and steam is generated in a secondary heat exchanger at 200 p.s.i. (abs) and 407°F.

* Associated in Great Britain with Humphreys and Glasgow, Ltd.



Cut-away drawing of reactor unit.

Enclosure

The enclosure was required to withstand the maximum energy that could be liberated by the most unlikely chain of events (a total of 8 sequential failures on the part of personnel and equipment) totalling some 7 million B.T.U. causing a pressure peak of approximately 65 p.s.i., and calculated to be equivalent to the firing of 75 lb of TNT.

To demonstrate the strength of the container, pressure testing with air was considered but found undesirable since the energy storage in about 56,000 cu ft (before insertion of the concrete) could lead to a disastrous accident if a rupture should occur, and hydraulic testing was decided upon. While this solved one problem, it introduced another, in the strength of foundations required. The vapour container now rests on a structure two or three times stronger than is necessary for operation simply because, to demonstrate its pressure integrity, it had to be filled with water initially.

Leak testing developed into an even more difficult task. The contents of the container could be allowed to leak at the rate of only 2 cu ft per day, which represented 1 part in 40,000. Even if the test pressure were raised to 4 times the operating pressure, it would still take 10 days before a pressure drop of 1 in 1,000 could be expected. While measurements of this accuracy might be obtainable even in the field, the fact that a ½ deg. rise in temperature would offset this leakage made it impossible to use pressure loss as a test method.

The extremely small leakages allowable led finally to use of a helium leak detector as the only device of sufficient sensitivity. The container was pressurized to 5 p.s.i.g. with a 10% helium in air mixture. The welds (previously 100% radiographed) were manually sniffed with a probe to demonstrate the absence of leaks. Not a single leak was found in 2,800 ft of weld.

Control Rod Drives

The control rod drives are mounted at the bottom of the reactor vessel so that the cover can be removed for refuelling

without the need for disconnecting the operating mechanism. The rods are actuated by a rack and pinion located below the reactor core, the pinion being driven through a shaft which brings the driving unit well out to one side of the reactor vessel. The penetration of the high-pressure region is accomplished through a labyrinth seal which includes the indicator drives and transmitters, the limit switches and the magnetic clutch for emergency release; all bench-assembled for ready replacement. The magnetic clutch releases the rods, rack, pinion and inner shaft from the gear motor to permit free fall of the rod when rapid shut-down is desired. A one-way clutch is included so that the motor can be used to start the rod downward in the unlikely event of sticking.

Sealing Problems

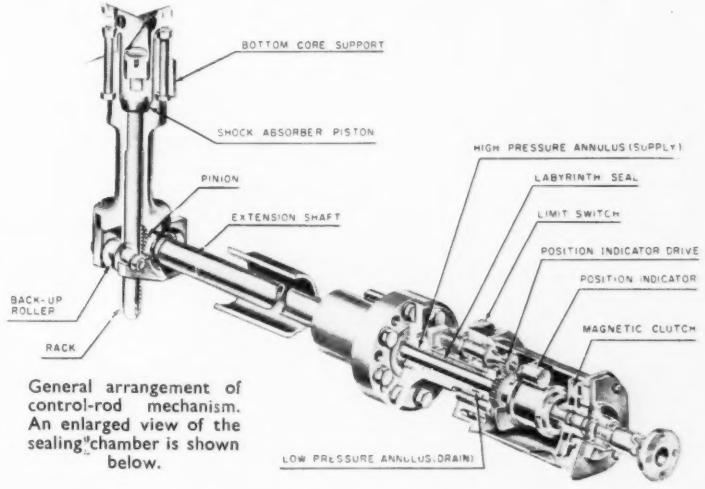
The labyrinth seal, regarded as an important development, incorporates an annular space into which clean fresh water is introduced at a pressure slightly above the reactor system pressure, so that no leakage of radioactive water is thus anticipated. At the time the tender was being prepared, development work on a seal had been under way for some time, but it was discovered, however, that leakage increased rapidly with time of operation, e.g., from 1-3 lb/hr to 10-20 lb/hr in about 48 hours, although periodic tightenings returned leakage to tolerable values. Since the radiation level during operation prevented access for such adjustment, a more stable seal leakage was deemed essential. A review of the detailed execution of the seal design indicated several small design errors, and correction of these led to a seal whose leakage over hundreds of hours increased by only about 50-60% from a starting value of 1 to 5 lb/hr, without adjustment.

Entire units have been subjected to 6,000 hours of continuous cycling operation, in which time 42,000 scrams have been performed with almost no malfunctioning. A slight stickiness near the bottom of the travel developed early in the test programme and this was corrected by increasing guide-pad clearances on the upper support plate, and truing up the rod baskets which had somehow come through inspection considerably diamond shaped. The test programme has been discontinued, in view of the fact that the number of cycles on several rods is sufficient for a life of 100-200 years.

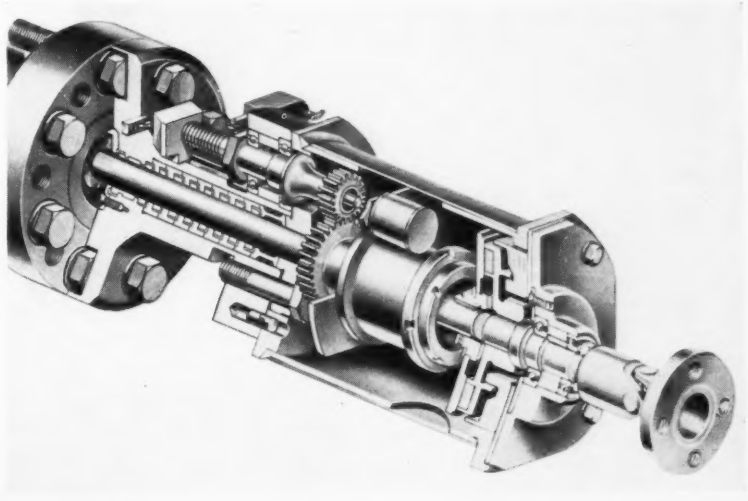
Control Rods

The selection of the location and number of control rods, an item of major importance, was based on experimental work done in the autumn of 1955 on a very tight time schedule; the reactor vessel being simultaneously designed in order that material orders and fabrication could be put in hand. As is the way with such experimental work, problems were encountered which necessitated slowing down the original schedule, to the point where an adequate definition of the reactor characteristics was not possible by the time a decision had to be made on the number of control rods.

Thus, although the original concept envisioned the use of only five control rods, alternate layouts were prepared showing seven and nine such rods fitting within the original core structure. Early experiments confirmed the belief that seven rods would be enough, and attention was directed to determining their proper location. Preliminary data from the experiment indicated that the centre control rod was about twice as effective as



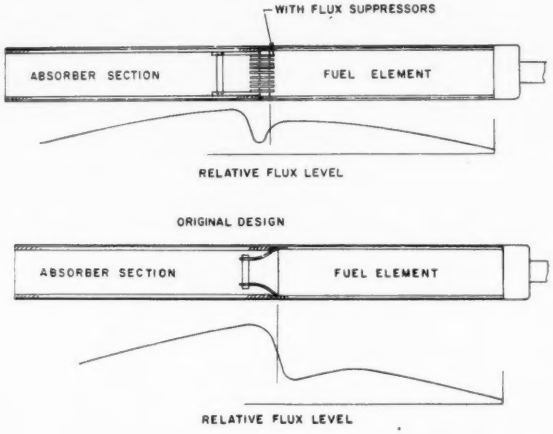
General arrangement of control-rod mechanism. An enlarged view of the sealing chamber is shown below.



Looking down into the core vessel during assembly.

A "dummy run." Practising inserting fuel elements with the vessel flooded.

(Below) Flux distribution with and without suppressors.



those in the four corner positions—a result which had been anticipated from the analytical survey. Unfortunately, the study for alternate locations of the sixth and seventh rods was carried out by studying the effectiveness of single locations of a mocked-up control rod. When all seven rods were installed at a much later date, it turned out that the interreaction between the various rods considerably reduced the efficacy of the sixth and seventh rods. However, this increase was sufficient to assure the ability to meet the design lifetime requirements of the contract. It is still hoped that operating experience will show that adequate control can be obtained with only five rods; so that future reactors will be cheaper and simpler.

Stress Corrosion

One of the major problems which developed during the design period, concerns stress corrosion of the stainless-steel tubes in the steam generator due to the pressure of chloride ions. The selection of stainless steel for construction of the primary system was based primarily upon the requirement of minimum corrosion, since corrosion products introduce a radioactivity problem throughout the circuit. On the secondary side, carbon steel was considered preferable since conventional corrosion rates and control methods were acceptable and since it is not susceptible to chloride stress corrosion. The presence of chloride is expected on an infrequent basis as a result of leaks in the condenser allowing cooling water (with Cl occasionally as high as 2,000 ppm) to mix with condensate.

The primary water was finally specified to have a max. of ½ ppm of chloride and an oxygen concentration of .005 cc/l. All information to date seems to indicate that with both of these variables controlled to these low levels, stress corrosion will not develop.

Reactor Vessel Seal

The reactor vessel is of stainless clad carbon steel 48 in. in dia (inside) and provided with a 28 in. dia opening through which the refuelling must take place. During 20 years of operation it is expected that this will be opened and closed 20-30 times. The closure selected involved a ring gasket with conventional stud and nut closures. An experimental programme was put in hand to establish the durability of both groove and gasket with repeated removal. First results indicated that the deformation with 304 stainless steel would cause eventual failure of the sealing surfaces. The experiments indicated that substitution of 17-4 PH in the ring groove would result in a harder material in the vessel than in the ring groove, to confine distortion to the replaceable ring. Preliminary tests at overlaying this material and heat treating it indicated that success could be expected. However, when it was applied to the reactor vessel, several attempts failed to produce an uncracked ring groove. A repeat check on a complete, although small-scale ring closure was attempted using 304 both in the ring and in the groove. This was assembled and disassembled a total of 20 times, hydrostatic and helium tests being applied frequently throughout the test. It was found that no significant deterioration of the ring groove was anticipated, although surface deformation did occur. Furthermore, the gasket which had been expected to be useless after a single application, was found to be successful after 10 applications, and was then replaced only for experimental information and not from necessity.

Control-rod Flux Peaking

The last major fabrication problem was encountered, in a sense, after the reactor started to operate. In the zero-power experiments run at Schenectady on the first core loading, a detailed and careful flux check of the entire core was obtained. In the course of this mapping, it was determined that a bad flux peak occurred in the upper end of the fuel portion of the control rods. Since the rods are one of the most important coolant flow control points in the core, the flux peaking indicated a high probability of boiling during normal operation.

The flux peaking was attributed to the existence of the large water hole immediately above the top of the fuel portion where neutrons generated in the fuel portion, and in adjacent fuel elements, are slowed to thermal levels in the water. It is characteristic of this situation that the flux level increases above the surrounding areas due to the fact that the low absorption of water in the region reduces their absorption rate. The uranium adjacent to this region, however (in this case at the top of the fuel), is subjected to a high flux and, therefore, has a high heat rate.

The cure for the problem was to reduce the peaking by introducing additional absorbing material at the top of the fuel plates, to depress the flux in this particular region. As the illustration shows, this was accomplished by inserting combs in the top of the fuel and brazing into position. These combs had to have a high cross-section for neutrons, be corrosion resistant and have reasonable structural strength. The final choice for this difficult set of requirements was Haynes-25 Alloy.

Glass Technology in the Nuclear Field

Some Manufacturing Problems Reviewed

THE two main aspects of glass in which the nuclear engineer is interested—apart from chemical glassware—are the availability of dense glass for radiation absorption and the problem of discoloration of glass due to the bombardment by radiation.

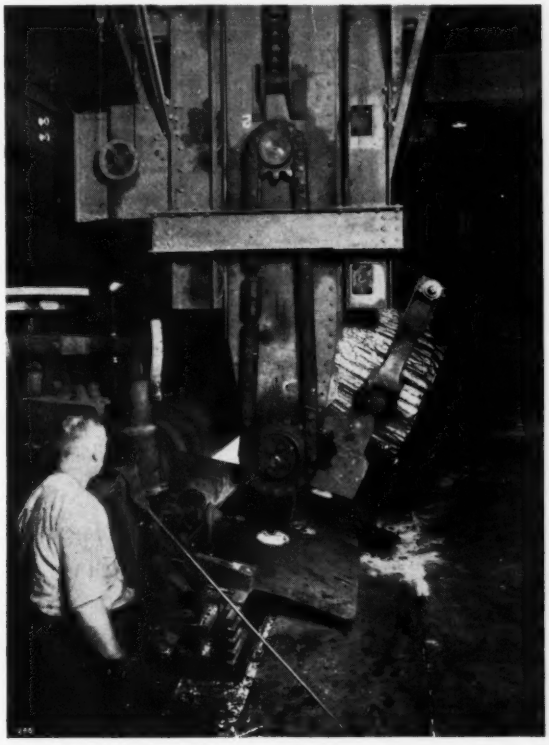
Heavy Glass

Lead glass has been used for X-ray shielding for a good many years but, with radiation at these energy levels, the problem is comparatively simple. Developments in the nuclear field have introduced a need for glass of greater and greater density to cope with the high levels of radiation, and glass containing 80% lead oxide is already marketed.

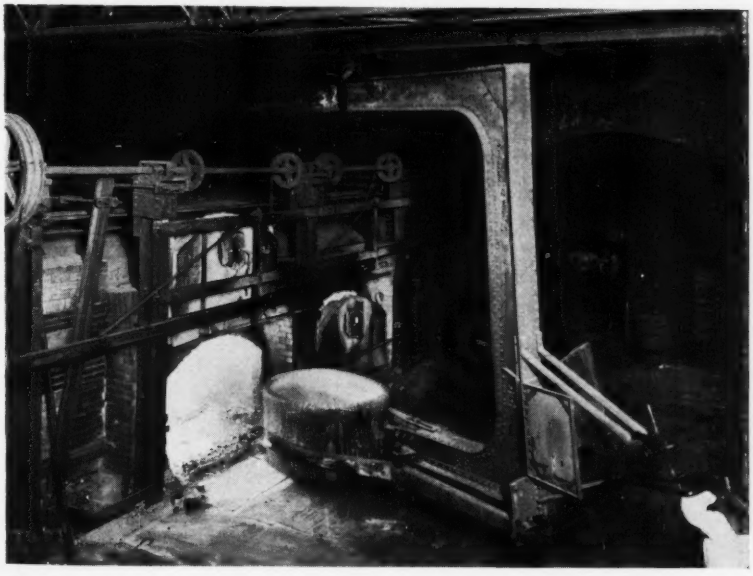
To those unacquainted with glass and its problems it would seem, on the face of it, a simple matter to manufacture glass of any desired composition, whereas, in fact, the practical difficulties are very considerable.

In the first place, it is often not generally realized that glass is not a true solid but a supercooled liquid and has, therefore, no definite melting point but a range of temperature over which it changes to a true liquid state via a plastic stage; this plastic range being the foundation of all glass working technique. Glass can only be rolled, for example, in a certain stage of plasticity—if too fluid it will not keep its form and if too viscous it cannot be worked.

Rolled glass manufacture. On the right is shown the pot of molten glass being tipped into the reservoir feeding the rollers.



(Below) A 1-ton pot being removed from the furnace on its way to the rolling machine.

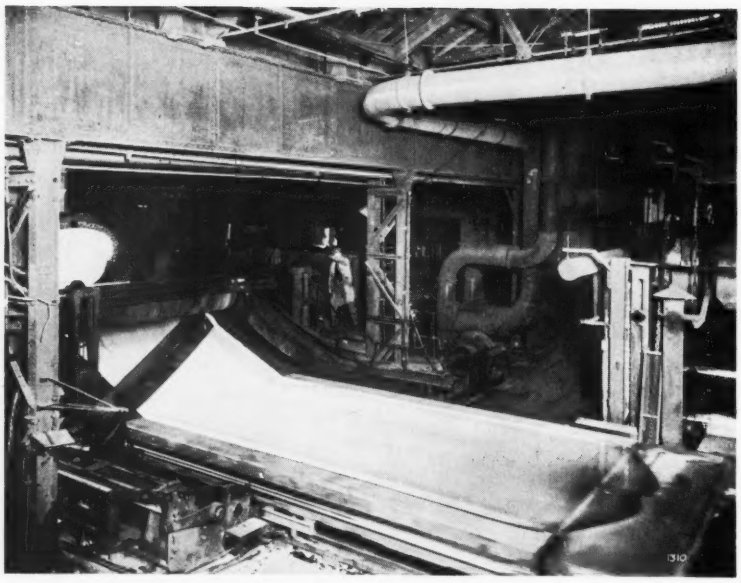


It is, therefore, desirable to have as long a working range as possible since it is not practicable to maintain the temperature during the actual working.

Glass manufacture also involves chemical problems in the refractory field. Most lead glasses attack pots made of the normal type of refractory material to a greater or lesser degree and the higher the lead content, the more serious is this attack.

Rolled Glass

It is possible to manufacture glass containing up to 60% lead oxide by a rolling process and this is carried out at the St. Helens Works of Pilkington Brothers Limited. The glass is melted in refractory pots of 1 ton capacity. The mix is melted at 1400°C and soaked at 1000°C at which temperature it is removed from the furnace by battery-electric fork trucks. The "metal" is then poured by a crane into a reservoir feeding rollers and, after rolling, the sheet is of rectangular



Rolled glass manufacture. The sheet is flowing down from the rollers on to the moving carriage. The inclined blade of the flying shear that will separate the sheets can be seen on the left.

shape and thickness of 28 mm. Passing through rollers, the sheet travels down an incline on to the surface of two moving carriages, the sheet being severed between the carriages by means of flying shears. The still hot sheet is then transferred by mechanical pushers to a lehr or annealing furnace, where it is allowed to cool slowly. It is cut up when cold into pieces of suitable size before it proceeds to the grinding and polishing department for finishing to 1 in. thick. This is, incidentally, the maximum thickness that is normally produced. Since the annealing time of glass varies as the square of the thickness, the difficulties increase with thickness.

Cast Glass

Heavier glasses lying outside the range that can be produced by rolling are made by Chance-Pilkington Optical Works. In this case the chemical nature of the glass precludes the use of normal pots, and the mixture is melted in special pots which limit the size of the melt that can be cast. Melted in this fashion, the glass is cast into moulds. The maximum size of block for glass of density 6.2 g/cc is 400 cu. inches.

It must be borne in mind that, until quite recently, the glass industry's incentive to develop high-density glasses has been from the optical standpoint, and the need for higher refractive indices, not gamma-ray absorption, has been the force behind the work carried out.

At the moment the thickest glass available in the form of large sheets is 1 in. and thick windows must be made by building up a multiplicity of plates. Developments are now in hand to produce blocks of heavy lead glass 4½ ft x 3 ft x 4 in. for large area protective windows.

Discoloration

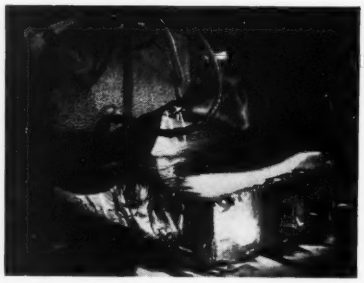
Glass discolours under radiation bombardment. The mechanism of this is still a matter for investigation and much theoretical and experimental work is in progress. It is known that the addition of about 2% cerium oxide to an ordinary melt gives a glass which has a straw colour but which does not change appreciably when irradiated. Similar stabilization is applied to lead glasses.

Lead Equivalent

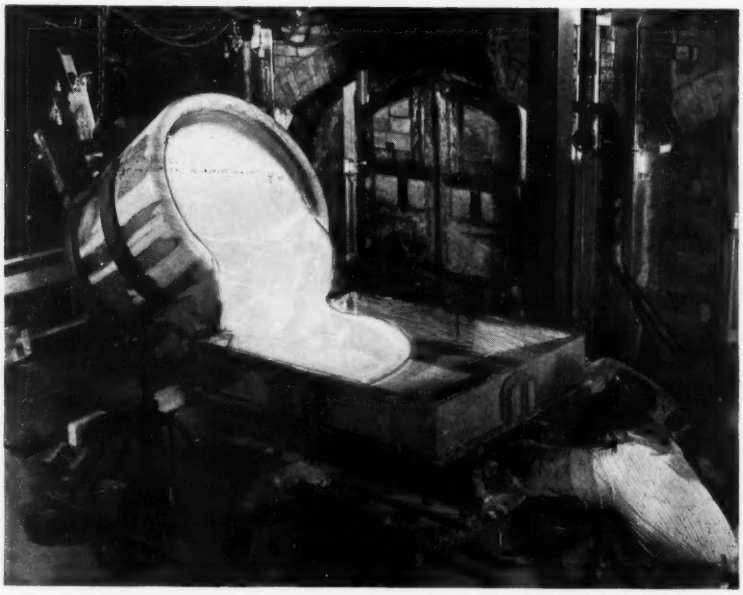
The following gives the "lead equivalent" of a number of types of glass, i.e., the thickness of metallic lead giving the same absorption of radiation from a Cobalt 60 source as unit thickness of glass. It can normally be calculated as 0.088 of the density in g/c.c.

Type	Lead Equivalent
OW7 (Stab)	0.38
OW8 (Stab)	0.54
927210	0.54
653335	0.34
700303	0.38
748278	0.42
801255	0.46
030181	0.59

Many nuclear engineers do not realize the glass maker's problems—that it is not possible to get merely for the asking any size or thickness of glass in any desired composition. On the other hand, the glass technologist is usually not provided with sources of high energy radiation. There is, however, continual collaboration between the glass makers and A.E.R.E. Harwell.



(Above) Sawing a thick block of glass. (Below) Casting a thick block of glass from a refractory pot.



Technical Papers and Publications

The O.E.E.C. Amsterdam Conference

THE second O.E.E.C. Information Conference on Nuclear Energy for Management was, as was emphasized in the opening addresses, rather less general in tone than the Paris conference held in April, and the treatment of the subjects rather more technical. Throughout, however, the emphasis was on the industrial side. There could be, said Dr. Kramer in his opening address, no question of isolated progress in the field of nuclear energy; the connection between the many branches of industry was nowadays too close, and development in one branch was bound to lead to consequences, however insignificant they appeared to be, in other branches. Industrial leaders could only accomplish the task of making nuclear energy economically available to the community if they were aware of all the possibilities.

Research

Limiting features of research were emphasized by Mr. Rennie. As experience was gained in reactor technology the amount of research required would tend to decrease but we were some way from this stage. At present and in the immediate future the two prime necessities were for adequate facilities and, no less important, adequate financial and technical effort. At present there was a shortage of suitable testing reactors but it seemed that in a few years' time the shortage would not be so much in reactors as in the technical and scientific man power to make use of them, unless steps were taken at once to correct this tendency.

Industry had a most important rôle to play in research, said Ir. W. A. de Haas. Nuclear physics was, at one time, the province of the university laboratory, and industry's part was the rather minor one of building a little high-voltage equipment and other laboratory apparatus. Now that research centres looked like factories, industry would have a larger part to play, but its rôle would still not be very large. In applied research, i.e. nuclear energy, industry would be called upon to undertake the building and sale of reactors and industry must start research itself or, at least, take an interest in joint research. Much of the research would have to be done, of course, in material testing reactors and would need large-scale effort, but there was a vast amount of what he termed "small" research that could be carried out by individual companies.

Industry must prepare for its task by commencing research in their own branch of work connected with the nuclear energy field. An industry should be in a position to criticize the specifications laid down and be able to judge and advise on, say, the necessity for expensive special materials.

Summarizing, Mr. de Haas said that industry had two different rôles to play. In nuclear physics, industry was to provide industrial experience, leaving the main work to be done by national or international scientific organizations. In the field of nuclear energy industry had a lot of research to do itself either individually, or as a co-operative effort.

Nuclear Fusion

Nuclear fusion was dealt with by Dr. A. S. Bishop in slightly more detail than one would have expected at a management conference; nevertheless, his lecture was clearly and simply explained. Dealing with the main problem confronting experimenters working on the "pinch" effect—that of instability—he mentioned one of the most encouraging approaches towards a solution. Computations made at Los Alamos had indicated that it should be possible to stabilize the pinch by axial magnetic fields within the centre of the pinched discharge. This, however, produced a number of other complications the severity of which had not yet been assessed.

On the question of neutrons produced under experimental conditions, he said that detailed study in the U.S., particularly at Livermore and Los Alamos, had led to the conclusion that neutrons were not thermo-nuclear in origin, but were produced by the instability of the pinch: by the very high voltages produced in the neighbourhood of the pinch instability accelerating a small fraction of the ions present to a high enough energy to produce neutrons when they impinged on other relatively cold ions in the plasma. Work in the U.S. was not by any means limited to the pinch effect; the approach was, in fact, following the same philosophy as for the fission programme, simultaneous pursuit of several different projects, including the Stellarator project at Princeton.

Fuel Processing

Delegates were given some idea of the cost of fuel processing in the paper by M. Sartorius (France), who briefly reviewed the methods of treatment before proceeding to economics. For a plant treating 1 ton/day of fuel based on natural or slightly enriched uranium the capital cost would be $20 million and the annual operating cost (assuming 10-year amortization) $4 million, the cost of treatment working out at about $20 per kilo for natural uranium up to $1000/kilo for highly enriched fuel. Nevertheless, bearing in mind the high cost of the materials themselves, $17/gramme for U^{235} or $12/gramme for plutonium, reprocessing represented only a comparatively small charge on energy costs.

The figures given by M. Sartorius did not agree exactly with those given by M. E. Saeland, lecturing on the O.E.E.C. project for a joint fuel processing plant. The study group set up by the 14 member countries in the autumn of 1956 had reported that the plant should be capable of treating a wide variety of fuel elements of natural and slightly enriched uranium. Although the capacity required for the first 3-4 years would not be likely to exceed 100 tons/year, design should be such that the capacity could be considerably extended by, say, 1964, without a large increase in cost. The first cost was estimated to be $15 million and the gross operational cost $1.6-2 million, not including amortization charges estimated at $1 million. The plant, which would require a staff of about 450, could be ready for operation in 1961. A number

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PAPERS PRESENTED

Introductory Addresses. **Dr. E. L. Kramer** (Netherlands) and **M. Pierre Huet** (O.E.E.C.).
"Nuclear Energy in Europe." **Prof. L. Nicolaidis** (Greece).

Research (2nd day). Prof. Nicolaidis in the chair.
"Basic Research." **M. Berthelot** (France).
"Applied Research." **C. A. Rennie** (U.K.).
"The O.E.E.C. Experimental Reactor Programme." **Dr. L. Kowarski** (O.E.E.C.).
"Nuclear Research Centres." **Prof. Rostani** (Italy).
"Research in the Field of Controlled Fusion." **Dr. A. S. Bishop** (U.S.A.).
"The Rôle Played by Industry in Research." **W. A. de Haas** (Netherlands).

Nuclear Fuels (3rd day). M. Herman Robiliart (Belgium) in the chair.
"Deposits and Prospecting." **J. Sornein** (France).
"Natural and Enriched Uranium." **Dr. W. B. Lewis** (Canada).
"Uranium Deliveries Under the American Programme." **J. A. Hall** (U.S.A.).
"Production and Utilization of Plutonium."
"Manufacture of Fuel Elements." **Dr. K. H. Hardy** (U.K.).
"Processing of Irradiated Fuel." **M. R. Sartorius** (France).
"The O.E.E.C. Project for a Chemical Processing Factory." **M. E. Saeland** (O.E.E.C.).

Energy Production (4th day). Mr. H. West (U.K.) in the chair.
"Nuclear Power Stations (basic equipment, construction, financing)." **Mr. H. West** (U.K.).
"Moderators." **M. P. Akar** (France).
"Structural Materials." **Dr. G. Matz** (Germany).
"Nuclear Propulsion." **Prof. T. J. Conolly** (U.S.A.).
"The Nuclear Power Programme in the U.K." **Mr. J. C. Duckworth** (U.K.).
"The French Programme." **M. Teste** (France).

Social Problems (5th day). Prof. Louis Buguard (France) in the chair.
"Radiation Effects and Background Activity." **Dr. H. Muth** (Germany).
"Protection of Workers and the Public." **Dr. H. Jammet** (France).
"Atomic Risks—Liability and Insurance." **Dr. W. E. Belser** (Switzerland).

of sites had been proposed. The Study Group was in favour of this joint undertaking being in the form of an international company.

Fuels

Further views on the vexed question of the relative advantages of natural and enriched uranium were given by Dr. W. B. Lewis (Canada), who commenced his paper by quoting the U.S. conviction expressed in Tokyo, that enriched uranium was a better fuel than natural uranium, regardless of the type of moderator used. "Fortunately for my task of discussing the relative merits of enriched and natural uranium for economic power reactors," said Dr. Lewis, "I do not share this conviction." Dr. Lewis's preference, in fact, seemed to be heavily on the side of natural uranium, but in association with heavy water. Nevertheless, his comparisons between the costs of different types were on a fair basis. In his conclusions he indicated that there was, in fact, no hard and fast ruling that could be applied. It did not appear, for example, that designers using enriched fuel had been able to achieve significantly lower capital costs. The pressure shells of the water-cooled reactors, for example, were smaller than for the gas-cooled, yet both designs approached closely to the limit of what was practicable to design and operate. It was possible, of course, that the U.K. design would be more expensive to build in the U.S. or Canada on account of the large amount of skilled work required on site, and the higher labour rates obtaining there. In fact, he pointed out with engaging frankness ". . . I can only present our present state of ignorance, and suggest that local circumstances rather than any basic virtue of natural or enriched uranium, would determine the choice."

A further point on which he disagreed with the official U.S. views expressed at Tokyo was on the use of uranium oxide. In work carried out in NRX under power reactor conditions, i.e. under high pressure high temperature water coolant, uranium oxide had given very promising results for long irradiation and minimum damage when in contact with hot water.

WORLD POWER CONFERENCE

OF the remaining* papers at the World Power Conference in Belgrade, the first three in the nuclear power section appear of the most general interest. These were "Cost of Small Nuclear Power Plants," by **Louis H. Roddis** (Deputy Director, Division of Reactor Development), "Nuclear Power Plants for Under-Developed Countries," by **H. S. Arms** (Chief Engineer of the English Electric, Babcock and Wilcox, and Taylor Woodrow Group) and a paper with a similar title by **W. E. Shoupp** and **A. R. Jones** of Westinghouse.

The first paper, by Mr. Roddis, was of interest in that it gave tabulated details of all the "small" U.S. power reactors as well as those of the major U.S. power reactor experiments; an exceedingly valuable feature. On the question of costs, however, the paper was hardly conclusive; indeed Mr. Roddis frankly stated that it had been a long standing conviction of his that in estimating costs, the type of reactor is less important than the person who does the estimating. It would seem, in fact, that the object of the paper was not so much to evaluate costs as to demonstrate the unreliability of many of the estimates being made in various quarters. The most important "unknown," in his opinion, was the operating life of the plant and many estimates were being based on widely varying degrees of validity. Even the definitions "small" and "economically competitive" were debatable. For his purpose, he proposed to define "small" as below 40 MW. electrical output. As for life expectancy, he fixed 30 years for conventional steam stations and nuclear stations, and 15 years for Diesel installations. He also felt that assumed load factors were unduly high and that 50% was a realistic figure for an average load factor over the life of a plant that started on a base load of 85% or over.

Of the tabulated results, it is only possible to quote first costs as no estimates were given for financing, for fuel or for other charges, so far as nuclear stations were concerned. Figures for first cost, however, in dollars per kW of capacity were: large steam, $132; small steam, $175, and Diesel, $270. For nuclear stations a survey of 14 U.S. plants showed a variation from $220/kW for Consolidated Edisons Indian Point station (250 MW) to $1,250/kW for the APPR (4 MW), the smallest considered. He emphasized, however, that these estimates were for plants that had not been built, and that multiple production of small nuclear plants was bound to lead to lower costs.

One of the most important points to be remembered, however, was that while all these first costs were estimates, there was some element of reality about them. Estimates of operating costs, however, depended entirely on fuel element life, and figures quoted were completely speculative, and only actual operation experience would give any reality to the picture.

Types of Reactor

Reviewing the various types of reactors available, the author stated that in his opinion the fast breeder reactor was unsuitable, on account of the very high enriched fuel inventory. The natural uranium fuelled, graphite moderated gas or water cooled types were also considered unsuitable because of their large size and high cost. Somewhat naturally, he strongly supported the pressurized water type. Boiling water reactors received only qualified approval, on account of their rapid changes in reactivity with load surges. Furthermore, carry-over problems were not yet fully determined.

Other types of reactors and some of their characteristics were reviewed, and an interesting point raised concerning corrosion problems in the homogeneous reactor LAPRE—1, where gold-clad stainless steel was used and, following a scratching of the gold cladding, a hole had been corroded in the stainless steel tube within five hours.

Under-Developed Countries

On the question of under-developed countries, Dr. Arms pointed out that the situation was usually complicated by local physical and economic circumstances and by political considerations as well as by the types of reactors available.

In the first place, he considered it essential that any country intending to embark upon a nuclear power programme should realize the necessity for a certain minimum amount of education and training in nuclear physics and reactor behaviour, and that education without a research reactor being available would take no one very far; a commercial power reactor was unsuitable for research purposes. The research reactors need not be very costly unless a country proposed to develop its own atomic power industry, in which case a materials testing reactor would be an essential tool.

In the field of power reactors it was felt that the gas-cooled graphite moderated reactor was the best for countries embarking on large-scale industrialization, one of its chief attractions being the use of natural uranium, giving greater independence in regard to fuel supplies.

In the case of a smaller country where potential demand was likely to be lower, a different type of reactor might be applicable. In the case of isolated industry, i.e., the development of a remote but valuable natural asset such as a mine, a packaged type reactor might be appropriate. As an example of a situation where nuclear power, even at a comparatively high cost, might still be competitive, he instanced the present cost of generation in some parts of the Arctic, which had been stated to be as high as 26d/kWh.

* The paper by J. A. Jukes was reviewed in our July issue.

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PWR Design

The third paper, by Dr. Shouff and Mr. Jones, although dealing with power plants for under-developed countries, did so from quite a different angle. Only the pressurized water type was considered; in fact the authors went so far as to say that . . . "it is probable that no other reactor type will, in our lifetime, compare in reliability, technical advance, or number of kilowatts installed, with the pressurized water reactor." Having thus defined their attitude they then proceeded to devote the rest of the paper to a most informative dissertation on design. In choosing the first unit the selection of size was important. It must be remembered that at least three years would be required to design and install a plant and load growth in the meantime must not be overlooked. The plant should not be too large—possibly a year of operation would be required for acquiring operational data and for education and training, and the operation of a large plant at light loads could be prohibitively expensive.

On the other hand, the unit rating should be as large as the area would utilize effectively, not only because a larger unit would operate more economically, but it would eliminate extrapolation of data for succeeding plants.

The Westinghouse company had concentrated development on four standard ratings of 11.5, 15, 68, and 143 MW gross electrical output and the paper then described the smallest and largest in some detail.

Space does not permit a full comparison, but one or two leading dimensions may be mentioned. Both plants are pressurized at 2,000 p.s.i.a., the steam pressures being 520 p.s.i.a. for the small set and 500 p.s.i.a. for the large unit. Although the capacity of the latter is more than ten times that of the smaller, the dimensions of their respective reactor vessels are 4 ft 10 in. and 9 ft 1 in. inside diameter and 18 ft and 33 ft overall height. The small plant utilizes a single steam generator of 6,200 sq ft tube surface, the large plant utilizes four steam generators, each of 16,000 sq ft tube surface. Both reactors are fuelled with pelletized uranium oxide clad in zirconium, but the small plant uses 12,240 rods 17 in. long whereas the large plant uses 23,218 rods 117 in. long.

BRITISH COMMONWEALTH WELDING CONFERENCE

Welding Reactive Metals. By F. G. Cox, Ph.D., A.R.C.S. (Principal Research Metallurgist, Murex, Ltd.).

Zirconium, tantalum and niobium all react rapidly at temperatures well below their melting points with all common gases, to the detriment of ductility; zirconium, for example, becoming brittle and unworkable with an oxygen content as low as 0.2% by weight. They also react vigorously at their melting points with all known fluxes.

Both argon-arc and resistance welding can ensure that molten metal does not contact any reactive material and that it is protected from the atmosphere. The argon process, as originally developed for thin magnesium, aluminium and stainless steel sheets will require modification in that it is necessary to protect the back of the weld as well as the face and the supply of argon to the torch must be increased; at normal flow rates traces of air are drawn in by thermal currents.

Given adequate protection all three metals are readily weldable: the use of filler rod is deprecated. Tantalum and niobium will show silvery bright faces; zirconium is invariably discoloured. A silvery weld in zirconium is often brittle.

D.C. welding is preferable to a.c., so that the heat is concentrated in the weld rather than the electrode, since the melting points of tantalum and niobium are approaching that of the tungsten electrode. In the case of thin zirconium, the smaller molten pool ensures less risk of contamination.

If a filler rod must be used its cross-sectional area should approach that of the V-groove in the sheet, so that, in effect, a single pass weld can be made and it should, preferably, be placed in the joint before welding.

Resistance welding uses conventional equipment. Contamination can be further avoided by welding under water or carbon tetrachloride.

Quantitative data are not available on the resistance welding of zirconium, but a good starting-point for development of a welding procedure would be that available for austenitic stainless steel. Faces to be welded should be cleaned and degreased by swabbing with acetone or carbon tetrachloride but, apart from weld contamination considerations, surface cleanliness is not particularly important.

THE INSTITUTION OF ENGINEERS AND SHIPBUILDERS IN SCOTLAND

Nuclear Power for the Propulsion of Merchant Ships. By S. L. Smith, C.B.E., D.Sc.(Eng.), and J. S. Richards B.Sc.(Eng.), Ph.D. (both of the British Shipbuilding Research Association).

This paper gives a broad picture of the present state of development and the technical and economic problems which remain to be solved, based on studies carried out by the British Shipbuilding Research Association. After comparing fuel cycles and costs the paper reviews the basic reactor designs and their respective advantages and disadvantages. On the question of prospects of commercial application of nuclear plant the paper gives results of a feasibility study for 47,000-ton single-screw tankers for which gas-cooled heavy-water-moderated reactors fuelled with natural uranium might be attractive. The study shows that the cargo carried in nuclear and conventional ships was the same when the additional machinery weight of the nuclear vessel did not exceed 1,700 tons. The permissible cost per shaft horsepower varied according to the additional machinery weight, the variation for a 16,000 s.h.p. ship of 15¾ knots being from £91 per s.h.p. for 500 tons to £61 per s.h.p. for 3,500 tons additional machinery weight. Comparable figures for a 22,000 s.h.p. ship of 17 knots were £58 and £35 per s.h.p. The figures were based on fuel cost of 0.2d. per s.h.p. hour. An increase or decrease of 0.1d. on this figure would result in a decrease or increase in the permissible total reactor cost of £530,000 for the lower-powered ship and £720,000 for the higher powered.

Under the heading of "Practical Considerations" the authors point out that with the extended burn-up necessary to achieve a low fuel cost it would be impracticable to assume that all fuel element changing could be done in harbour although on-load element changing would be expensive and difficult to arrange. Enriched fuel would give more scope in element design.

The use of natural uranium would necessitate a dump condenser, since thermal cycling of the fuel elements would be unacceptable and it would probably be impracticable to build in sufficient excess reactivity to avoid difficulty in re-starting due to xenon poisoning. With enriched systems it might be possible to manœuvre by variation in reactor power.

On the question of safety, the importance of natural circulation of coolant in the case of a pump breakdown was emphasized. Difficulties in overall containment of a pressurized water reactor were also stressed; the organic moderated reactor should not present the same problems. Normal risks of collision and fire must not be overlooked, and the possible spread of activity following a sinking would require experimental work; it might be necessary to specify a maximum corrosion rate for fuel elements in salt and estuarine waters.

Summarizing, the authors considered that the prospects of nuclear power applied to merchant ship propulsion was likely to be affected by the shortage of enriched fuel, but the low direct fuel costs of natural uranium reactors might well make them commercially attractive for large ships in the near future. It would take some 3-4 years to develop a natural uranium heavy water reactor and the prospect of such development might well depend on the prospects for enriched fuel in the early 1960s. An immediate project would probably use a gas-cooled graphite moderated reactor, possibly with enriched fuel.

The AEA Annual Report

Year of Solid Achievement

AFTER such a year of solid achievement the 1956-57 annual report of the U.K.A.E.A. could hardly fail to make impressive reading. In addition the presentation is particularly clear and whilst the text does not make too many concessions to the non-technical reader there should be no difficulty for the layman to obtain a comprehensive understanding of the record aims and future programme of the Authority.

With the continued relaxation of security restrictions it is not surprising that the report contains little that has not already been openly discussed but a brief summary is appended of some aspects of the year's progress which have not received wide publicity.

Finance

Net expenditure of £68,242,000 for 1956-57 was approved by Parliament in February of last year and to meet increases in salary and wages and an expansion of uranium production a further sum of £3,735,000 was approved in March. Estimates for 1957-58 submitted to Parliament in February this year represented an increase of nearly £27 million to cater for additional constructional work and staff increases. In spite of the revision of the original 1955 White Paper programme (increasing installed capacity from 2,000 MW to 5,000-6,000 MW by 1965) the £60-70 million estimated expenditure by the A.E.A. on auxiliary plant and prototype equipment is not expected to change. The C.E.A.'s investment for the revised programme is estimated at £742 million plus £177 million for initial fuel charges. To assist in financing the A.E.A.'s projects the Authority will grant, to groups developing the Calder type reactor, a non-exclusive manufacturing licence in return for a royalty on each reactor sold. The Authority also undertakes to keep companies informed of developments.

A significant source of revenue is the sale of radioisotopes. Sales for 1956-57 of which half were exports grossed over £500,000—£154,000 direct from Harwell and £387,000 from the R.C.C. Amersham, showing an increase of 12% over the previous 12-month period. The availability of irradiation holes in DIDO and PLUTO should give further impetus to this business.

Uranium

Information on latest uranium supplies became declassified under the tripartite agreement in December last, and, soon after, the U.S.A., Canada and South Africa published comprehensive figures. France followed later but Australia, the Belgian Congo and Portugal are not included in the aggregate annual production figure of at least 13,000 tons U_3O_8 in the western world. Annual production in the West is expected to be around 40,000 tons by 1959. Although sufficient supplies for the U.K. are assured for years to come, the Authority nevertheless feel that vigorous prospecting should continue, and development be encouraged by giving production guarantees and technical assistance.

Fuel Elements

A considerable proportion of the Authority's development effort is concerned with the investigation of canning materials and testing of fuel elements. The Calder Hall elements, for example, have been subjected to an extensive series of tests, in facilities simulating operational conditions, in the Windscale reactors. To improve the rating of the Calder type reactors it is hoped to increase the fuel can temperatures from 400° C to 600° C, which would permit a net electrical output of 400 MW from one reactor. Uranium oxide ceramic fuels and beryllium canning are being actively considered with this in mind, and loop tests will be performed in the three M.T.R.s which will shortly be available.

Successful tests in NRX (Chalk River) have been carried out with central fuel temperatures up to 2,000° C. Some beryllium canned elements have already been tested out of pile, and in-pile tests are now proceeding. Cermet elements tested include dispersions of uranium dioxide in aluminium and steel.

Advanced Reactors

The original concept of a three-stage development programme has now been abandoned in favour of a more flexible system, due to the much greater possibilities of the gas-cooled graphite moderated reactor than were at first foreseen and the doubtful advantages of the sodium graphite reactor. In addition the demands for ship propulsion units and small reactors are assuming greater importance. Recent calculations indicate that even with natural uranium as fuel a gas-cooled reactor can be built with an economical output as low as 30 MW (E), and a feasibility study is under way.

A zero-energy high-temperature gas-cooled reactor working on the thorium-U^{233} cycle is to be built for physics measurements, and is scheduled for completion in 1960. The ceramic fuel, which will not be canned, is rated at 800° C and a semi-dispersion in the moderator is contemplated, making the system quasi-homogeneous. This type of reactor system could be applicable to large and small generating stations as well as to ships.

For large ships, with quick turn-round and high payload, such as tankers, it is still possible that the Calder type reactor might be suitable. Alternatively, particularly for units under 20,000 s.h.p., the organic or heavy water moderated, gas-cooled systems offer considerable possibilities of rapid development. A decision will be taken this year on which of these two systems should receive higher priority.

Fusion

Little detail is given of the work in hand, but a large-scale apparatus for studying plasma behaviour under the influence of magnetic fields is nearing completion. Temperatures of several hundred thousand degrees have already been achieved, and it is hoped with the new equipment that fusion will be detectable.

Acceleration

In collaboration with the Weapons Group and industry, Harwell is developing a 12 MeV tandem accelerator. The design of a 6-7 GeV proton synchrotron is also well advanced and, if the project should go ahead, this accelerator will be one of the main instruments of the National Institute for Research in Nuclear Science.

Reactor School

Accommodation is now available for 60 students at the Harwell reactor school, following the move into new quarters in September last. Up to and including the first course in 1957, 471 students had passed through the school, of which 84 were from overseas and 280 from British companies. In addition, 62 industrialists passed through the short course designed for senior executives with a technical background.

The eight-week course on operations which started at Calder Hall in January will, in future, be extended to six months.

Staff

Total numbers employed by the A.E.A. increased from 23,973 on April 1, 1956, to 27,290 on March 31, 1957. Of these, non-industrial staff increased from 10,795 to 12,630 and industrial employees from 13,178 to 14,660. As in past years, the most difficult posts to fill were the senior posts in engineering; and special efforts were necessary to fill vacancies in the more remote stations. In general, however, the problem of staffing is not serious and atomic energy continues to hold out attractive possibilities as a career.

This aerial view of Berkeley was taken after 5½ months' work on the site. Special construction methods have eliminated the use of heavy cranes. The heat exchangers are being built in the long shed in front of the nearest reactor pit. (A.E.I.-John Thompson Nuclear Energy Co. Ltd.).

World News

International

Element 102—the tenth artificial element created since the end of the war—was discovered by an international research team comprising scientists from Britain, Sweden and the United States.

The new element was made at the Nobel Institute, Stockholm, by bombarding the artificial isotope Curium, deposited on a thin metal foil, with carbon ions accelerated to a high energy in the Institute's 225-cm cyclotron. The isotope that resulted has a half-life of about 10 minutes.

Members of the team were: Dr. John Milsted and Alan Beadle (Britain), Hugo Atterling, Wilhelm Forsling and Lennart Holm (Sweden) and Paul R. Fields and Arnold M. Friedman (U.S.A.).

Establishment of an O.E.E.C. uranium processing plant is desirable and practical Mr. E. Saeland of O.E.E.C. announced in Amsterdam on June 26. The maximum processing capacity during the first three or four years of operation (1961-64) would not exceed 100 tons annually. Capital cost is estimated at $15m with running costs at $1.6m to $2m per year excluding capital charges.

Low energy synchro-cyclotron at the site of the twelve-nation European Organization for Nuclear Research (CERN) is due to operate at the end of this year. A second and more powerful accelerator—a proton-synchrotron of 25,000 to 30,000 MeV—will be completed in three years, according to CERN's annual report published on June 28.

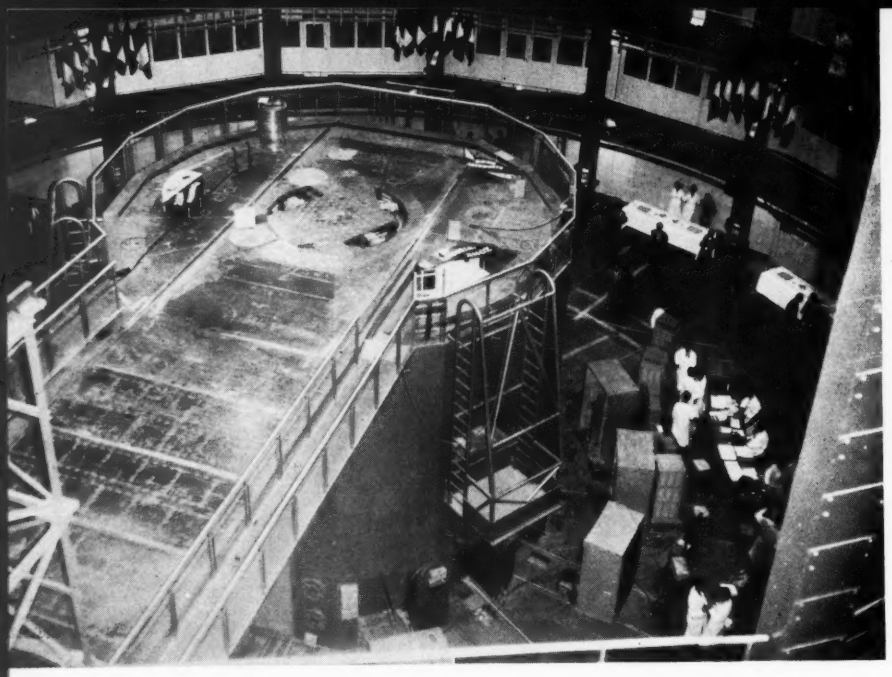
Seventeen-nation working group to deal with problems arising from the proposed establishment of an Asian regional nuclear centre in Manila met in Washington for a series of talks on July 8. One of the greatest difficulties to be overcome is the severe shortage of nuclear scientists and technologists. The seventeen nations comprise the U.S. and members of the Colombo Plan consultative committee.

Third International Conference of Ionisation Phenomena in Gases arranged by the Italian Physical Society and held in Venice from June 11-15 was attended by about 300 scientists. Great interest was shown in the realization of thermonuclear energy from high-temperature plasma. Several papers from the U.S., U.K. and Germany were devoted to the theoretical considerations of the heating and stability of possible discharge systems. On the experimental side systematic work on the emission of neutrons by high current pinched discharges between electrodes was described by workers at Livermore (U.S.), A.W.R.E. (U.K.) and Upsala (Sweden). Studies on the high current ring discharge were described by workers at Saclay (France), A.E.R.E. and A.E.I. Ltd. (U.K.). Details of temperature, stability and spectroscopic measurements were given.

Provisional agenda for the Second International Conference on the Peaceful Uses of Atomic Energy has now been published by the Department of Public Information, United Nations, New York. The conference takes place in Geneva from September 1-13, 1958. Invitations have been sent to all 81 U.N. members, together with the German Federal Republic, the Republic of Korea, Monaco, San Marino, Switzerland, Vatican City and Vietnam.

The provisional agenda provides for a series of general sessions on subjects including the future of nuclear power, experience with nuclear power plants, use of nuclear energy for purposes other than production of electricity, the possibility of developing thermonuclear power, progress in the use of radioactive isotopes and health and safety aspects of nuclear power programmes. In addition there will be four series of technical sessions on specific problems of nuclear development.

Concurrently with the Conference, the Salon International des Applications Pacifiques de l'Energie Atomique a Genève (place du Lac 1, Genève) is to organize a commercial exhibition.



General view of the new EL 3 pile inaugurated at Saclay research centre, Paris, on July 4. The pile uses uranium enriched to 1.4% with U_{235} with heavy water as a moderator.

United Kingdom

Lord Mills, Minister of Power, has given consent to the construction of a nuclear power station at Hinkley Point, Bridgwater Bay, Somerset. The contract for this station —which is expected to cost between £60m and £70m will be placed in September; work will start immediately.

Good progress is being made at Berkeley, Gloucester (John Thompson-A.E.I. Nuclear Energy Co. Ltd.) and Bradwell (Nuclear Power Plant Co. Ltd.). Our aerial view shows the Berkeley site after less than six months' work.

At a Press conference in London on July 18, Sir Claude Gibb, chairman and managing director of N.P.P.C., announced the award of sub-contracts for Bradwell equipment to 255 companies. He said that the total number of sub-contracts would probably total 1,000. Sir Claude also commented that N.P.P.C. could today design a nuclear power station of over 400 MW for a capital cost in the region of £115/kW.

No announcement has yet been made about the proposed Hunterston nuclear power station which is to be built by the G.E.C. Simon-Carves group for South of Scotland Electricity Board.

Private three-day conference on controlled thermo-nuclear reactions took place at A.E.R.E. Harwell from June 20 to 22. Delegates included U.K. and U.S. research workers and about 100 representatives from British industry. Purpose of the conference was to examine some of the practical problems and to endeavour to secure the assistance of industry in overcoming them. Much of the information has not been declassified.

Special advisory committee set up by the British Insurance atomic energy committee has now submitted its report on nuclear insurance. The committee recommends that the whole insurance market should collaborate to afford the maximum possible protection because of the high cost of a reactor. It also suggests that responsibility for radiation damage should be channelled to the reactor owner who can cover his liability by third party insurance. Copies of the report are obtainable from the British Insurance Association, 59-67 Gresham Street, London, E.C.2.

Proposal for a common policy on the development of nuclear power in the Commonwealth was put forward during the meeting of Premiers in London early in July. It is hoped to convene a conference of nuclear scientists to study collaboration.

Preliminary research on the application of nuclear power to aircraft is being undertaken by the Ministry of Supply, Mr. W. J. Taylor, Parliamentary secretary, told the Commons. It has been suggested that the three Princess flying-boats could be used for test purposes.

Africa

Two South Africans, Mr. A. R. Newby-Fraser and Mr. J. R. Colley, will carry out research on heavy water production at Harwell as part of a recently-concluded agreement between U.K.A.E.A. and the S. African Atomic Energy Board. The agreement provides for a full interchange of nuclear information.

"Atoms for Peace" agreement signed by S. Africa and U.S.A. on July 8 will enable the Union to buy up to 500 kilograms of 20% enriched uranium; six kilograms of 90% uranium and research quantities of U233, U235 and plutonium.

S. Africa's investment in uranium extraction plants and ancillary sulphuric acid production facilities totals £60m sterling, according to Dr. A. J. A. Roux, research and planning director of the Atomic Energy Board. When all plant was in production the annual value of uranium oxide exports would be nearly £50m, he said.

Australia

Atomic Energy Commission signed contract for purchase of 11 short tons of heavy water from U.S.A.E.C. Senator Wm. Spooner, National Development Minister, told a Press conference on July 3 that the heavy water cost approximately £10 sterling per lb; it will be used in the Lucas Heights reactor.

Deposit of highly radioactive ore discovered a quarter of a mile from Radium Hill mine in South Australia.

Canada

Official opening ceremony of the 200 MW NRU research reactor is scheduled sometime this month. NRU will provide Canada with first-class research and experimental facilities in addition to substantial quantities of plutonium and radioactive isotopes for industry and medicine.

Geological Survey of Canada will, at the request of Atomic Energy of Canada Ltd., make a special study in an attempt to find a safe method of dispersing radioactive waste from the Chalk River, Ontario, nuclear energy plant.

France

National Assembly voted 342 to 239 to ratify the European common market and Euratom treaties on July 9. The Advisory Council of the Republic is confidently expected to concur in this decision.

Prior to the ratification the Assembly approved the expenditure of £235m on atomic energy development in the next five years. Of this £25m will be towards a £60m uranium isotope separation plant. It has not yet been finally decided whether this will be built by France alone or, as seems possible, shared with other Euratom signatories.

Marcoule site was opened to the Press on July 16. Visitors were shown over the reactors G1, G2 and G3, and over the plutonium production plant. During the opening discussions M. Pascal gave details of the burst slug, which kept G1 out of action from October to January this year. During the burst (which must have been caused by a blocked channel, although direct evidence is not available and the cause of blockage cannot be ascertained) three-quarters of the length of one can burnt and some uranium was transferred. There was no personnel hazard and special manipulation equipment was devised to clear the element and clean and repair the channel. On restarting the reactor was taken rapidly up to full load and has since given no trouble. A small number of conventional slowly-developing pin holes have since been observed. For further details of atomic energy in France see Commentary (page 309).

Germany

Agreement on co-operation for the peaceful use of atomic energy signed between W. Germany and U.S. on June 28. For research purposes the U.S. will ship up to 6 kilograms (13 pounds) of enriched uranium containing not more than 20% of U^{235}; up to 100 grams of pure U^{235}; 10 grams of plutonium and 10 grams of U^{23}.

On July 2 a constitutional amendment to enable the Federal Govt. to develop atomic energy for peaceful purposes failed for the second time by two votes to gain the necessary two-thirds majority. As a result the Bill is to be redrafted: the government now hopes it will become law in the last session of this parliament.

Contract with the U.S. for the purchase of 2,500 kilograms of enriched uranium was signed on July 19. Dr. Siegfried Balke, Federal Atomics Minister, hopes shortly to conclude a contract with Canada for 500 tons of natural uranium.

Bundesrat (Upper House) unanimously approved the common market and Euratom Bills ratified by the Bundestag (Lower House).

Bundestag committee for atomic questions will recommend that Germany should build a Calder Hall-type of nuclear power station, Dr. F. Corterier, a member of the committee, said after a visit to Britain. The committee suggests that a station could be built on Hardtwald island on the Rhine near Karlsruhe.

Method of enriching uranium by centrifuging has been developed by Prof. Wilhelm Groth of Bonn University.

S.I.M.A.—British Scientific Instrument Manufacturers' Association—will feature a wide range of instruments at Interkama, Dusseldorf, from November 2 to 10 this year.

Hungary

Mr. Arpad Kiss, president of the Hungarian State Planning Bureau and vice-president of the A.E.C. said on June 26 that the Commission would resume work shortly. Hungary is to build a nuclear power station with Soviet assistance.

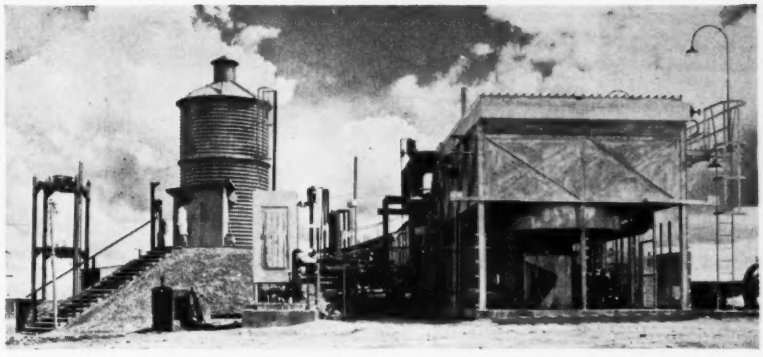
Japan

Mr. Koichi Uda, Japanese Minister of State and chairman of the A.E.C. seems to be in favour of a Calder Hall-type reactor following his visit to Europe, and the United States. During his tour, Mr. Uda and his delegation visited both Calder Hall and the Berkeley station in course of construction.

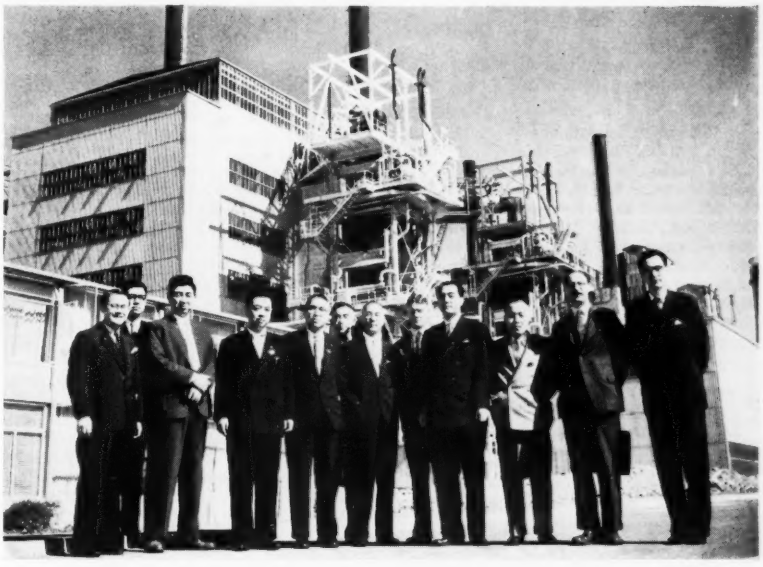
Netherlands

Judging by the reaction of British visitors, "Het Atoom," the International Atomic Exhibition opened at Schipol airport, near Amsterdam by Prince Bernhard of the Netherlands on June 28, is a great success. Apart from the Mitchell A.M.F. demonstration reactor, British exhibits include a model of the proposed Scottish station (G.E.C.,

(*Continued on page* 346)

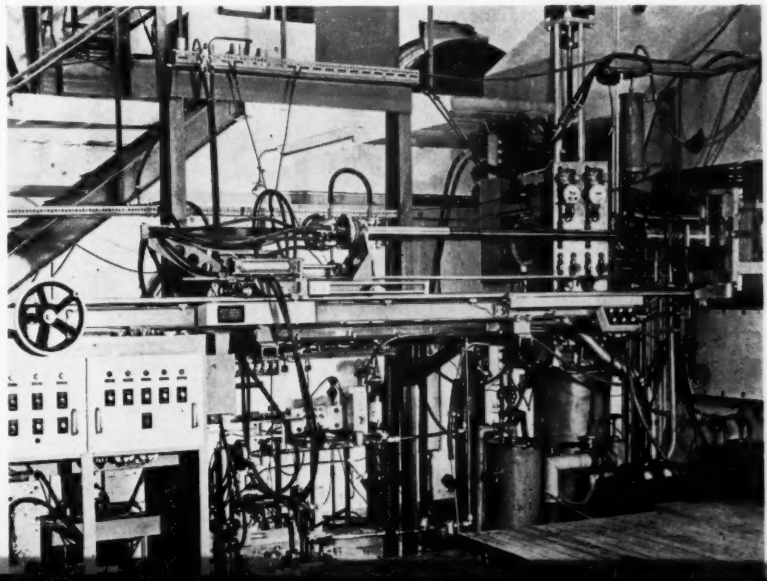


Construction of the Organic Moderated Reactor Experiment (OMRE) is essentially completed according to the company responsible, Atomics International. The object of OMRE, located at the U.S.A.E.C.'s national reactor testing station at Idaho Falls, is to prove the feasibility of a power reactor moderated and cooled by a hydrocarbon.



Mr. H. G. Davey (fifth from right) poses with the visiting Japanese delegation at Calder Hall nuclear power station. On Mr. Davey's right is Mr. Koichi Uda, chairman of the Japanese Atomic Energy Commission.

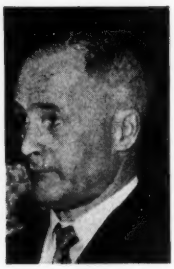
The coils and magnet of the cyclotron at the Nobel Institute, Stockholm, where a new element, 102, was recently discovered by a joint Swedish-U.S.-U.K. team. The head of the target probe contained the curium 244 which absorbed carbon 13 ions to form the new element which it is proposed to call Nobelium.



Mr. I. M. Stewart.

Lord Bridges.

Sir Roy Dobson.



Mr. E. Mensforth.

Mr. G. W. Hall.

Personal

Appointments

Mr. Iain Maxwell Stewart, B.Sc., A.M.I.Mech.E., M.I.N.A., M.I.Mar.E., and the **Rt. Hon. Lord Bridges,** P.C., G.C.B., G.C.V.O., F.R.S. as directors of Babcock and Wilcox, Ltd. Mr. Stewart is chairman and managing director of Thermotank Engineering Co. Ltd. Lord Bridges retired from the Civil Service in the autumn of 1956 and was created a Baron in the New Year's Honours List, 1957.

Hawker Siddeley John Brown Nuclear Construction, Ltd.

The Board of Directors of this new company comprises: **Sir Roy Dobson,** C.B.E., Hon. F.R.Ae.S., J.P., chairman; **Sir Arnold Hall,** F.R.S., M.A., Hon. A.C.G.I., F.R.Ae.S. (both directors of Hawker Siddeley Group, Ltd.); **Sir William Scott Farren,** C.B., M.B.E., F.R.S., M.A., M.I.Mech.E., F.R.Ae.S. (technical director of A. V. Roe and Co., Ltd.); **Mr. E. P. Hawthorne,** B.A., A.M.I.Mech.E., A.F.R.Ae.S. (director and chief executive of Hawker Siddeley Nuclear Power Co., Ltd.); **Sir Stanley Rawson** (vice-chairman of John Brown and Co., Ltd.); **Mr. Eric Mensforth,** C.B.E., M.I.Mech.E., F.R.Ae.S., and **Mr. R. J. Barclay** (both directors of John Brown and Co., Ltd.); and **Mr. V. A. Pask,** C.B.E., M.I.C.E., M.I.Mech.E., M.I.E.E., F.I.S. Mr. Pask retired as chief engineer of the British (now Central) Electricity Authority in 1955.

Mr. H. G. Herrington and **Mr. G. C. R. Eley** have been appointed directors of the Hawker Siddeley Group Ltd.

Mr. Herrington is managing director of High Duty Alloys, chairman of Templewood Engineering Company, and a director of Hawker Siddeley Nuclear Power Co. Ltd.

Mr. Eley is chairman of the Brush Group, which was recently acquired by Hawker Siddeley.

Mr. P. Goudime, M.A., managing director of Electronic Developments Ltd., elected president of the Scientific Instrument Manufacturers' Association. He succeeds **Mr. G. A. Whipple,** M.A., M.I.E.E., F.Inst.P., chairman and managing director of Hilger and Watts Ltd., who now becomes vice-president. **Mr. R. Barrington Brock,** M.B.E., F.R.I.C., B.Sc., director of Townson and Mercer Ltd., also elected vice-president (president-elect). Other S.I.M.A. officers for 1957-8 are **Mr. L. A. Woodhead** (Cossor Instruments Ltd.), hon. secretary and **Mr. P. J. Ellis,** O.B.E. (R. B. Pullin and Co. Ltd.) hon. treasurer.

Mr. H. A. Luss, joint managing director of Isotope Developments Ltd., appointed chairman of the Nuclear Group of the Scientific Instrument Makers' Association. He is now also deputy chairman of Isotope Developments Ltd. **Mr. E. W. Jones,** B.Sc., A.Inst.P., has been appointed sales manager of the company.

Mr. G. W. Hall, F.R.Ae.S., a half brother of the late **Sir Richard Fairey,** as chairman of the Fairey Aviation Co. Ltd. Mr. Hall, who retains his appointment as managing director of the company, was elected acting chairman following the sudden death of **Mr. R. T. Outen** in February.

Mr. Eric G. Fielding, publicity manager of Vickers Ltd., elected president of the Incorporated Advertising Managers' Association.

Mr. Paul K. Jennens, Mr. Stanley R. Brown, and **Mr. George A. Laskey** as directors of Temple Press Ltd., publishers of *Nuclear Engineering*.

Mr. F. B. Duncan, and **Mr. J. S. Woodrow,** chairman and managing director respectively of The Pulsometer Engineering Co. Ltd., have joined the Board of Self-Priming Pump and Engineering Co. Ltd., following the acquisition of the company's issued share capital.

Dr. W. M. Gibson, lecturer in physics at Queen's University, Belfast, appointed to the scientific staff at the Geneva Centre of the European Organization for Nuclear Research. He will take up his new post on October 1.

Mr. F. A. Klouman has retired from executive duties with J. Blakeborough and Sons, Ltd., but continues as deputy chairmain and will act as consultant to the company. **Mr. W. R. Blakeborough** has been appointed managing director. **Mr. F. T. Bintcliffe** has joined the Board and will remain in office as secretary.

Mr. B. W. Balls, B.Sc., M.I.Chem.E., to be technical sales manager and **Mr. A. H. Isaac,** B.Sc., A.M.I.Chem.E., to be manager of the Sales Engineering Department of Foxboro-Yoxall Ltd.

Mr. P. Goudime.

Mr. E. Fielding.

Mr. E. W. Jones.

Mr. B. W. Balls.

Mr. A. H. Isaac.

Sir Nevil Macready.

Dr. Schonland.

Appointments (contd.)

Sir Nevil Macready, Bt. as manager of Supply Department of Mobil Oil Company.

Mr. H. W. Bishop has been appointed a director of C. E. Harper Aircraft Co. Ltd.

Mr. N. A. Hart of Baldwin Instrument Co. Ltd., is now responsible for Publicity for the Harper Group of Companies. These include Harper Aircraft Co. Ltd., Exeter, Devon; Stanley Engineering Co. Ltd., Egham, Surrey; H.M.C. Wheels Ltd., Hornsey, London, N.8; and Electrical Screw Ltd., London, N.16.

Dr. J. A. Scott, O.B.E., F.R.C.P., Q.H.P., as Chairman-Elect of the Royal Society of Health. He will assume office on October 1.

Mr. Alexander L. Hoop has been appointed a director of George Wimpey and Co.

Mr. Robert Ritchie, northern manager, as technical director of Klockner Moeller England Ltd.

Mr. G. C. Baker as a director of Amber Chemical Industries Ltd.

Mr. R. Fraser as publicity manager for the Richardsons, Westgarth group of companies.

Mr. A. T. Johnston, general manager, and **Mr. R. G. Lyttelton** have been appointed directors of Guest Keen and Nettlefolds (Cwmbran).

Mr. G. W. H. Richardson has been appointed a director of the Westinghouse Brake and Signal Co. Ltd.

Mr. N. L. G. Lingwood, distribution director of British Oxygen Gases Limited, re-elected President of the British Acetylene Association. He has held this office since 1956.

Mr. M. Seaman has moved from the Board of British Oxygen Engineering Ltd. to the Board of British Oxygen Gases Ltd., where he will be director responsible for equipment manufacture.

Mr. F. W. Skelcher, M.I.E.E., M.I.Mech.E., Chief Generation Engineer (Operations) as Deputy Chief Engineer (Generation and System Operation) of the Central Electricity Authority.

Mr. Richard Hermon has joined the Board of the Butterley Company. **Mr. H. R. Newman** and **Mr. Hermon** have been appointed joint managing directors.

Mr. Thomas E. Murray, who failed to win reappointment as a member of the U.S. Atomic Energy Commission, was named as a consultant to the U.S. Joint Congressional Committee on Atomic Energy.

Mr. Bernard G. E. Stiff of Lynnfield Center, Mass., as manager of United Shoe Machinery Corporation's atomic power department.

Mr. Robert K. Winkleback as assistant manager of American Machine and Foundry Company's nuclear engineering laboratory.

Awards

Sir Christopher Hinton, K.B.E., F.R.S., awarded the gold Albert Medal for "outstanding leadership in nuclear power development."

Mr. A. F. Pexton, the first holder of the *Nuclear Engineering* Scholarship, awarded a Clayton Fellowship by the Institution of Mechanical Engineers.

Tours

Dr. C. H. Bhabha, chairman of the Indian Atomic Energy Commission and secretary of the Atomic Energy Department, visited British nuclear power station sites and research centres during June.

Professor J. M. Otero, vice-president and general manager of the Spanish Atomic Energy Commission, led a delegation of 11 scientists for a week's visit to U.K. nuclear stations in July.

General Jorge Sarmiento, head of the Atomic Energy Board of Peru, arrived at Southampton on June 28 for a three-week visit to nuclear installations. The tour was arranged by the British Council in conjunction with U.K.A.E.A.

Dr. Basil Schonland, deputy director of A.E.R.E., Harwell, visited the Rhodesian Federation in June to discuss a new research programme for radioactive minerals in the country with U.K.A.E.A. officials in Salisbury. The programme includes an aerial survey of about 6,000 square miles of territory in the north-west of Southern Rhodesia and the examination of rivers which may drain uranium-bearing rocks. Dr. Schonland also visited Tanganyika and South Africa.

Mr. W. A. Hartop, works director of George Kent, Ltd., is on a round-world tour, the main object of which is to stimulate and expand the company's export markets. He will spend about four months with the Kent organization in four Commonwealth countries.

Retirement

Mr. Harold Scholey, special director of English Steel Corporation, director and general manager of English Steel Rolling Mills Corporation, retired on May 31 after 55 years with the company and its predecessors.

Obituary

Nuclear Engineering records with regret the death of the following personalities:

Lord Cherwell, who died at the age of 71 on July 2, will be remembered for his part in the establishment of U.K.A.E.A. As Paymaster-General from 1951 to 1953 he took charge of the British atomic development programme. After Sir Edwin Plowden became chairman of U.K.A.E.A. in 1954 Lord Cherwell remained associated with the Authority.

Dr. R. W. L. Gawn, C.B.E., R.C.N.C., Superintendent of the Admiralty Experiment Works, Haslar, died on July 10 at the age of 73.

Mr. Walter C. Kerrigan, vice-president and general sales manager of The International Nickel Co., Inc., died in New York on July 16. He was 74.

Films

British Atomic News.—A 30-minute colour film telling the story of industrial developments in nuclear engineering. The opening deals in a general way with the rapid exploitation of nuclear energy in Britain leading up to the opening of Calder Hall. This is followed by four separate sequences covering the work that is being done by four companies: Costain-John Brown, Ltd.; L. E. van Moppes (Industrial Diamonds), Ltd.; Morgan Crucible Co., Ltd.; and Edwards High Vacuum, Ltd. The film is intended to be the first of a series dealing with industrial aspects of nuclear engineering. 16-mm. or 35-mm. copies are available on hire from British Atomic News, Ltd., 3 Albemarle Street, London, W.1.

Nucleonic Measurement is the title of a 16-mm. black-and-white sound film now in the final stages of production for the Baldwin Instrument Co., Ltd. As the title implies, this industrial-documentary film explains the principle of radioactive thickness gauging with, of course, particular reference to the Baldwin Atomat thickness gauge. Sequences have been shot on location at Venesta, Ltd. (aluminium foil), Wiggins, Teape (1919), Ltd. (paper), Albert E. Reed and Co., Ltd. (board), and London Abrasives, Ltd. (abrasive papers). On completion, prints will be available on free loan from Baldwin Instrument Co., Ltd., Dartford, Kent.

Atoms for Peace.—A Soviet documentary on the industrial uses of atomic energy, this film has a running time of 75 minutes. Shots include several types of Russian reactors and there are a number of animated diagrams. A full account is given of Soviet applications of radioactive isotopes in industry, agriculture and medicine. 35-mm. colour and 16-mm. black-and-white copies available on hire from Plato Films, Ltd., 18 Greek Street, London, W.1.

Orbits in Industry

THE recent visit to Amsterdam for the opening of "Het Atoom" was an eye-opener in many ways. As emphasized in the review appearing on p. 327, this was neither another Geneva nor a trade fair; it was intended to sell the idea of nuclear energy to the people of the Netherlands who, presumably, have got to dig down into the pockets of their jeans to finance it. From this point of view it should be an outstanding success, since the exhibition itself and the way in which the theme is put over would fire the imagination of a tortoise (a noticeably advertisement-proof type). Even seeing it the way we see all exhibitions—a shambles of packing cases, wet paint and lethal chunks of timber wielded by infuriated carpenters—one could see that it was going to be out of the ordinary, and at the opening when the usual overnight miracle had been performed this impression was more than confirmed. Whoever planned this exhibition, and so ingeniously tucked so much into such a comparatively small space, had nothing to learn about display.

Prestigemanship

It has always been fashionable, when describing any overseas exhibition, to slate Britain for her poor display compared with the other nations. "When in doubt, have a crack at the Board of Trade . . ." seems to be the guiding principle. So let us, for once, try something different. Both the B.o.T. and the A.E.A. had done their best, but it seems more than peculiar that British industry was so indifferent. Only one of the consortia, G.E.C. Simon-Carves, had supported the exhibition, the remainder being, apparently, quite uninterested. It is true that this was not a trade fair and that no orders would be likely to ensue from it. Nevertheless, the U.S. had, to use a vulgar colloquialism, done their nuts to make an impressive show.

British industry, or a large section of it, still seems to work on the principle of R. W. Emerson that if you can build a better mousetrap than the other man . . . the world will beat a pathway to your door. This may work in the mousetrap industry (we haven't export statistics to hand) but it won't work in nuclear engineering. Prestige counts and we can't go on for ever on the Calder story. Holland has got to have nuclear energy—if only to excavate some more of her territory out of the sea—and it would be a thousand pities if she went to the U.S. or France for it; if only from sentimental reasons. The Dutch came over and showed us how to drain the Fen country (after, incidentally, giving us a few lessons in seamanship) and it would be nice to return the compliment after some three hundred years.

Wonderful Steam!

"Wonderful thing steam, sir." "Ah!" (a deep-drawn sigh) "it is indeed, sir." "Great power, sir." "Immense—immense!" "Great deal done by steam, sir." "Ah!" (another sigh at the immensity of the subject, and a knowing shake of the head) "you may say that, sir." "Still in its infancy, they say, sir." . . .

When Mr. Chapman (or it may, of course, have been Mr. Hall) chuckled over the proofs of young Mr. Dickens' first published work, it is more than probable that none of them realized that, over 120 years later, not only would all three of them still be famous but the words would still be almost true. Steam can hardly be said to be in its infancy but, until fuel element temperatures allow of a gas turbine cycle, or the fusion boys give us direct electrical generation from hot plasma, steam can only be considered to have reached a healthy middle-age. It is still the vital link between nuclear fission and useful energy, and its properties and behaviour are of vital importance—hence the prominence given to the research into boiler circulation on page 324 of this issue.

The behaviour of a water-steam mixture—as a homogeneous fluid or with steam travelling faster than water—may seem of academic interest, but it is really of vital importance, as heat transfer rates get higher and higher. To take an extreme case, think of one of the experiments in the Harwell reactor school, where the loading of a heating element is governed by the velocity of the water flowing over it, and "slugging" or violent ebullition is only a short head in front of the burning-out of the heating element, and apply it to practical heat exchanger design. We may be, in our little corner, playing about with temperatures and pressures that "old-fashioned" fuels discarded a long time ago but, make no mistake about it, we are in what the Dutch would call the "steam kettle" business, just as deeply as any of the Smoky Joes.

Research at Cambridge

An interesting feature of the W.T.B.A. trip to Cambridge, by the way, was to see the other work going on in the Engineering Department labs. At one time, Universities were regarded as quiet backwaters for the pursuit of pure research, and those choosing the academic life as men reluctant to face the bustle of the busy work outside. If anyone still has this illusion, they should read the annual report of the Department or, better still, persuade the authorities to extend the same hospitality as the Press party received, and they would soon realize their error. The applied research being pursued on a commercial basis varies from the W.T.B.A. work already described to M.o.S. work ranging from gas turbine compressors to non-linear servomechanisms; gas discharge research for A.E.I. and liquid metal research for the A.E.A. This, of course, quite apart from work carried out for the sake of knowledge itself, plus, of course, the simple chore of instructing (at various levels) some seven or eight hundred undergraduates.

Sackcloth and Ashes Dept.

Taking the cane in strong right hand, and assuming the this-hurts-me-more-than-it-hurts-you attitude of our erstwhile headmaster (the old wounds still give trouble in frosty weather) a correspondent has us on the mat for the use of the word "fissionable" instead of "fissile"; his objections being based on the grounds that it is ungainly, un-standard and un-English. In apologizing for our lapse, we can only excuse ourselves on the grounds that our mind was running on Miss Nancy Mitford who, we believe, said (or should have done, anyway) . . . "Nowadays, it's fissionable to be U". . . . Which doesn't really get us anywhere, does it?

Science in Sport

The news that the A.E.C. has issued a licence for a reactor to be operated on the Oklahoma State Fairground makes one wonder if this is merely an exploitation of the novelty-value of a reactor, or whether it is yet another example of the trend towards a more scientific outlook even in our relaxations. Or perhaps even a return to the Victorian tradition of . . . "This Ingenious Device, Combining Amusement with Instruction, can Hardly Fail to Appeal to Persons of Taste and Sensibility. . . ." In this case shall we see the side-shows adopting an equally scientific approach? The Dodge'm, for example, renamed the Moderator (All the Thrills of Multiple Elastic Collisions!), the Orbital Spin, the Electron Shell, the Barkhausen Jump and the Cathode Drop! Couples wishing for the seclusion once found in the old-fashioned Tunnel of Love, will find it in the Cloud Chamber, while others more intent on prize winning will make for the skittle alley (a cokernut for every Compton Scatter!) or to the various other amusements (Your Personal Dosage Guessed to within One Millirad! . . . See the Lady with the Black Body Radiation!!). Tangent, of course, not being much inclined for amusement (even combined with instruction) will merely concentrate on refreshments. You will find him in the little tent modestly labelled "Tea and Hot π."

Tangent

Industrial Notes

Manufacturing Agreements

Hawker-Siddeley Group Ltd., and **John Brown and Co., Ltd.,** have jointly formed a new company called **Hawker Siddeley John Brown Nuclear Construction Ltd.** with a capital of £500,000. The first task of the company will be to design a nuclear-propelled vessel—probably a tanker with a gross weight of 60,000 tons. For the time being correspondence to the company should be addressed to 8 The Sanctuary, Westminster, London, S.W.1. A full list of directors appears on page 342 of this issue.

Babcock and Wilcox Ltd., in collaboration with **Cammell Laird and Co., Ltd.,** have completed a feasibility study of a 65,000-ton nuclear-powered tanker using a gas-cooled graphite moderated reactor design developed from Calder Hall.

Richardsons Westgarth and Co., Ltd., have acquired a controlling interest in Parsons Marine Turbine Co., Ltd. Previously the companies had associated on a number of marine engineering projects. The nuclear side of marine development is in the hands of a separate company, Richardsons Westgarth Atomic, Ltd., with offices at 58 Victoria Street, London, S.W.1.

The Pulsometer Engineering Co., Ltd., of Reading has acquired the issued capital of the **Self-Priming Pump and Engineering Co., Ltd.,** of Slough.

Hopkinsons, Ltd., of Huddersfield, have purchased a majority holding in Fielden Electronics, Ltd., of Wythenshawe, Manchester, 22.

John Laing and Son Ltd., and the **H. K. Ferguson Company of Great Britain Ltd.,** have formed a separate association in the name of Laing-Ferguson. The new concern will provide a complete and comprehensive construction service to the chemical, processing and manufacturing industries.

John Holroyd and Co. Ltd., of Milnrow, Lancs, and the **De Laval Steam Turbine Company**, of Trenton, 2, New Jersey, have jointly formed a new U.S. company, De Laval-Holroyd, to market and subsequently manufacture the Holroyd range of worm gears and worm speed reducers.

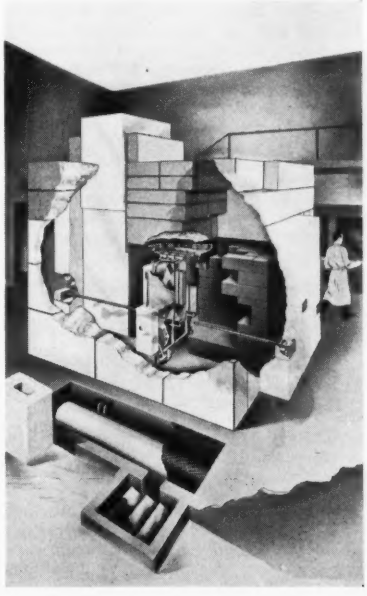
The Stabilag Co. Ltd., of Hemel Hempstead, Herts, have concluded an agency agreement with Voigt and Haeffmer A.G., Frankfurt, Main, under which the latter company will supply 12 different types of rod and tube industrial immersion heaters.

The Krupp Organization has acquired a 28% interest in Kropfmuhl, the Munich graphite manufacturers. Kropfmuhl are already making nuclear-quality graphite.

Thorn Electrical Industries Ltd., has acquired Nash and Thompson Ltd. of Oakcroft Road, Chessington, as part of its policy of widening the company's interest in the field of electronic and allied instruments. The new directors, Mr. D. Talbot and Mr. B. C. Fleming have said that the broad policy ot Nash and Thompson will remain unchanged.

N.D.A. Europe has been jointly formed in Brussels by the Nuclear Development Corporation of America (N.D.A.) of White Plains, New York and Societé Generale des Minerais of Brussels. Societé Belge pour L'Industrie Nuclaire (Belgonucleaire) is also a participant. N.D.A. Europe's registered office is at 31 rue du Marais, Brussels.

A.M.F. Atomics Division of American Machine and Foundry Company and Dr. Walter H. Zinn's General Nuclear Engineering Corporation have jointly agreed to produce training reactors for use by universities and industry. The new A.M.F.-G.N.E. Educator Reactor is claimed to be an improved version of the Argonaut design. It is rated at 10 kW for continuous operation.



Artist's impression of the 10 kW research and training reactor which is to be produced jointly by A.M.F.-G.N.E.

The A.P.V. Co., Ltd., of Crawley, Sussex, has concluded an agreement with the Rosenblad Company of Stockholm, Sweden, for the exclusive manufacture and sale of the Rosenblad Heat Exchanger in Great Britain. A.P.V. will also be responsible for its sale in the Commonwealth, except Canada, and in the Middle East. The manufacturing and selling rights were previously held by Ashmore, Benson, Pease and Co.

Contracts

A.M.F. Atomics Division awarded contract for a 1 MW pool-type research reactor by the joint Italian industrial groups, Fiat and Montecatini.

Solus-Schall, Ltd., awarded contract by Taylor Woodrow, Ltd., for gamma radiography of a 10-in. diameter pipe line from Port Hardcourt in Nigeria to Oloibiri near Kuglo, 60 miles away.

Head Wrightson Processes have been awarded a contract by the Danish Atomic Energy Commission for the design, engineering, procurement and erection supervision of a PLUTO Materials Testing Reactor. Like DIDO, PLUTO is an enriched uranium heavy-water-moderated reactor with a flux of 10^{14} neutrons per cm^2/sec at a thermal output of 10 MW. The reactor will be erected at the Atomic Research Centre at Risø. It is due for completion before the end of 1959.

Talbot Stead Tube Co. Ltd. have received a contract from C. A. Parsons and Co. Ltd. for components at Bradwell nuclear power station. The order includes fuel element support assemblies, charging standpipes, neutron source assemblies, absorber rods, short charge plugs, control rods and control rod standpipe plug assemblies to a total value of nearly £¾ million.

British Lead Mills Ltd., an associate of Simmonds Aerocessories Ltd., have supplied large quantities of lead bricks for shielding purposes to U.K.A.E.A. for the Dounreay project.

Wakefield Dick Industrial Oils Ltd. have been nominated by C.E.A. as suppliers of lubricants to Berkeley nuclear power station.

Griffin and George Ltd., of Alperton, Wembley, Middlesex, awarded contract for laboratory furniture in the new Chance-Pilkington optical and ophthalmic glass works at St. Asaph, Flintshire.

Taylor Woodrow Construction, Ltd., have been awarded a contract by Somerset County Council for the construction of an access road from Cannington, near Bridgwater, to the site of the proposed nuclear power station at Hinkley Point.

The contract involves the widening and improvement of existing stretches of road, together with the construction of new sections, including bridges and culverts, to provide nearly six miles of road. Work will commence immediately and the contract period is six months.

Excavation will amount to about 100,000 cu. yd. Some 85,000 tons of stone of varying grades will be used as filling and base material, and 77,000 sq. yd of tarmacadam surfacing will be laid.

Change of Name or Address

Avo Ltd. is the new name for Automatic Coil Winder and Electrical Equipment Co., Ltd., of Avocet House, 92-96 Vauxhall Bridge Road, London, S.W.1.

Klockner Moeller England Ltd. have moved to new premises at 7 Charterhouse Buildings, Goswell Road, London, E.C.1. (Telephone, Clerkenwell 0778.)

Temple Press Ltd., publishers of *Nuclear Engineering*, have moved their Birmingham office from 7 John Bright Street, to Bayliss House, Hurst Street, Birmingham, 5. The new telephone number is Midland 6616 (seven lines).

William H. Capper and Co., Ltd., of Forward Works, Woolston, Warrington, have opened a separate sales department at Mayfair House, 9 Hertford Street, London, W.1.

G.K.N. Reinforcements, Ltd., is the new name for Twisteel Reinforcement, Ltd. The company is a subsidiary of Guest, Keen and Nettlefolds, Ltd., with offices at 43 Upper Grosvenor Street, London, W.1.

Norris Warming Co., Ltd., heating, ventilating and air conditioning engineers, and **F. A. Norris and Co., Ltd.,** constructional steel-work engineers, have opened new offices at 38-40 Elm Grove, Portsmouth.

Dewhurst and Partner Ltd. have moved offices in Newcastle and Nottingham. The area manager at Newcastle is Mr. Ford and the new address is 46 Great North Road, Newcastle-on-Tyne, 2. In Nottingham the area manager is Mr. Owen and the new address is Bentinck Buildings, Wheeler Gate, (Telephone: Nottingham 40214).

Henry Hargreaves and Sons Ltd., of Cook Street, Bury, Lancs, have opened a London office at 603 Grand Buildings, Trafalgar Square, W.C.2. (Telephone: Whitehall 4805.) Mr. Cyril F. Morgan, L.R.I.B.A., A.M.I.Mech.E., is technical manager for the London area.

Honeywell-Brown, Ltd., have moved their Manchester branch office to larger premises at Warsall Road, Northenden, Manchester, 22.

Expansion

Elettrografite di Forno Allione—the chief Italian graphite producer—has an expansion scheme in hand to increase production of graphite by 60%. The company has a technical assistance agreement with the **Union Carbide International Company** of the United States.

Schori Division of F. W. Berk and Co. Ltd., of Brent Crescent, North Circular Road, London, N.W.10, have recently taken delivery of a new demonstration van which the company proposes to use for giving instructions on metal and plastic spraying at customers' works.

Westinghouse Electric Corp., have now decided to go ahead with the construction of a materials-testing reactor at Waltz Mill, Pa., 29 miles south-east of Pittsburgh.

Air Control Installation Ltd., of Ruislip, Middlesex, recently celebrated their 21st anniversary. The company now has 565 employees making fans, humidifiers, filters and a full range of air and dust control equipment. An extension of 15,000 sq ft is nearing completion.

Atomics International, a division of North American Aviation Inc. is now occupying a new 140,000 sq ft building in Van Nuys.

The Glacier Metal Co. Ltd. have recently moved into a new three-storey building opposite their main London factory at Alperton. The company specialize in the manufacture of bearings.

Stothert and Pitt Ltd. of Bath have established a new department for research and development. Mr. N. E. Kerridge assumes responsibility.

Nuclear Development Corporation of America of White Plains, N.Y., has purchased a 63-acre tract in Greenburgh, N.Y., to serve as a research and development centre.

World News

(*Continued from page* 341)

S.-C.); special radiation-proof glass (Chance Bros. Ltd.) and underwater television showing nuclear fuel and control rods (Pye Ltd.).

American-Dutch treaties on non-military use of nuclear energy and the statute of the International " Atoms for Peace " organization have been ratified by parliament.

Portugal

United States will contribute $50,000 toward the cost of a nuclear research reactor project at the research centre near Lisbon. On June 9 Portugal signed an agreement with the U.S. covering the supply to Portugal of uranium 235 and plutonium.

Sweden

U.S.A.E.C. has approved the sale to Sweden of 26 metric tons (28.6 tons) of heavy water for a prototype district heating reactor which is to be installed by Aktiebolaget Atomenergi in a Stockholm suburb.

Switzerland

Four principal Swiss electricity companies have formed a company called Suisatom, with an initial capital of about £500,000, to build an experimental nuclear power station.

U.S.A.

Major construction of the Dresden Nuclear power station, Illinois, began on June 12. This plant, which is being built by General Electric and the Nuclear Power Group of companies, will be operated by the Commonwealth Edison Company. The boiling water reactor will produce 180 MW: date of completion is 1960.

Symposium on the application of nuclear power to the propulsion of merchant ships is to be held in the General Accountancy Office Building, Washington, D.C., on July 30. The sponsors are the Maritime Administration, U.S. Dept. of Commerce and the A.E.C.

Democrats in the U.S. Congress are pressing for a Government-sponsored programme for building power reactors. They suggest that $210m should be spent. Under the threat of cutting off A.E.C.'s funds they have so far been 25% successful as about $50m has been promised for four small power reactors. These will be at Elk River, Minnesota (22 MW); Piqua, Ohio (12.5 MW); Big Rapids, Michigan, and Chugach, Alaska (10 MW each).

President Eisenhower announced on July 3 that the U.S. was increasing to 100,000 kilograms the amount of U235 it would make available for peaceful use at home and abroad. Previously, 40,200 kilograms had been designated for sale or lease. Of the extra 59,800 kilograms, nearly half will be sent overseas.

Grants totalling $2.45m have been approved by the A.E.C. for reactor research projects in seven countries under the " Atoms for Peace " programme. The money is being paid by the International Co-operation Administration from Mutual Security funds. The seven nations are: Brazil, Denmark, the Netherlands, Spain, Japan, Portugal and Venezuela.

Some 50 industrialists from the Euratom countries have just spent two weeks visiting a dozen or so completed or partially completed reactor installations and research centres. Object of the tour was to show how the U.S. could contribute to Euratom's programme to provide 15,000 MW by 1967. Talks were also held with representatives of the Export-Import Bank.

U.S.S.R.

Nuclear power station of 420 MW is in course of construction as part of the 1956-60 five-year plan which calls for a total capacity of 2,500 MW produced by nuclear fuel. The new station, scheduled for completion in 1960, will have two reactors each powering three 70 MW turbo-alternators. Fuel will be a mixture of natural and enriched uranium, with pressurized water as a moderator and coolant.

The Lenin—a 16,000-ton icebreaker, which will be nuclear-powered—may be launched at Stalingrad later this year. *The Lenin* is about 440 ft long with a 90-ft beam; the speed in open water will be approx. 18 knots.

Processes and Equipment

New Type of Particle Accelerator

Metropolitan-Vickers Electrical Co. Ltd. have been asked by U.K.A.E.A. to collaborate in the design of two tandem electrostatic generators for use at A.E.R.E., Harwell, and A.W.R.E., Aldermaston. These machines will enable research to be carried out into the nuclear properties of uranium and similar elements.

Compared with the familiar Van de Graaff accelerator the tandem generator has the novel feature that acceleration is achieved in two stages. Negative hydrogen ions are first accelerated from earth potential to an energy of 6 MeV. They are then fired into a "stripper," which removes the electrons from the outer shells of the atom and leaves the ions still moving in a forward direction with a net positive charge, but with energy almost unchanged. The second stage of acceleration is achieved by bringing the positive ions back to earth potential, so that the total energy communicated to the ions is 12 MeV. In this way, ions are accelerated to an energy twice as great as could be achieved in a single stage, whilst the insulation problems are exactly the same as in a single-stage machine. As a general rule, negative ions are more difficult to form than positive ions, and therefore the beam current in a tandem machine is smaller than in a single-stage machine, but this is a small price to pay for the saving in insulation.

The generator is housed inside a pressure vessel 45 ft high and 9 ft in diameter, which contains an insulating belt mounted on pulleys some 16 ft. apart. The belt moves at 3,000 ft/min, and electric charge sprayed on to its lower end is carried to the central terminal where the charge is collected. The charge leaks back to earth through two potential divider chains, one going to the lower and one to the upper end of the vertical column. To reduce the danger of voltage breakdown, the spaces between the central terminal and the upper and lower ends of the column are each subdivided by 150 equipotential plates, connected to the potential divider chains at the appropriate tapping points. The accelerator tube is housed inside the "stack" of equipotential plates and passes right through the ends of the pressure vessel. The tube is subdivided by conducting rings, each connected to its corresponding equipotential plate, the aim being to limit the voltage across any one section of tube to 40 kV.

Negative ions are formed in a high-frequency gas discharge and are withdrawn from the discharge by preliminary accelerating electrodes designed to produce a focused beam of circular cross-section and fire this down the centre of the main accelerating tube. Electrons are stripped from the negative ions by passing them through an extremely thin foil inside the central terminal. On emerging at the lower end of the accelerator tube the beam is passed through a magnetic field adjusted to deflect the ions through a right angle and bring the beam to a focus on the particular target under investigation.

Operation of a high voltage electrostatic generator necessitates "pressurizing" the vessel containing the accelerating electrodes. In this case the gas pressure is 250 p.s.i., and the weight of gas in the main pressure vessel is approximately 2 tons. For maintenance purposes this gas must be removed and stored in suitable containers; a considerable proportion of the cost is associated with the equipment for transferring the gas from reservoirs to the pressure vessel and keeping it dry and free from atmospheric contamination.

In the equipment described, the ions may move distances of about 120 ft before reaching their target, and the target area must not exceed a few millimetres in diameter. It is thus necessary to maintain a very high vacuum throughout the entire ion path and also to control all the accelerating and deflecting fields to a high degree of accuracy. The accelerator tube is pumped at the top and bottom, and also via a by-pass tube at the centre, by 14-in. mercury diffusion pumps with large dry-ice traps and liquid air traps in series. The accelerating, focusing, and deflecting fields are controlled by electronic stabilizers to an accuracy of a few parts in 100,000.

The higher available energies of the machines will permit the study of nuclear reactions produced by the bombardment of uranium and the transuranic elements. By bombarding suitable light element targets with beams of protons and deutrons, it will be possible to produce neutrons of controllable energy in the range up to 30 MeV, and to study their interaction with other nuclei. Other possibilities include the acceleration of heavier ions such as those of oxygen and fluorine.

(Metropolitan-Vickers Electrical Co. Ltd., Trafford Park, Manchester, 17.)

Fast Reactor Crane

The large rotating crane, weighing 85 tons, intended for the fast reactor at Dounreay was recently completed at the Glasgow works of J. H. Carruthers and Co. Ltd. The crane is 115 ft long and 47 ft high and it rotates on a circular track 83 ft in diameter. After tests at the works the crane will be dismantled and taken to Dounreay. It will be taken inside the sphere, piece by piece, through a small entry shaft, before being reassembled on the floor above the reactor.

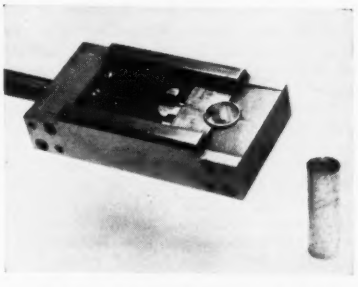
The crane will mainly handle the reactor charge and discharge machine. One of the many safety devices installed is a height indicator giving the precise position of the two hooks when they are below the reactor floor level and out of sight.

The crane has two independently controlled lifting trolleys 40 ft above floor level, and the hooks have a lifting range of 78 ft. One hook lifts up to 25 tons and the other can take 7½ tons.

(J. H. Carruthers and Co. Ltd., 27 Hamilton Street, Glasgow, S.2.)

Remote Handling

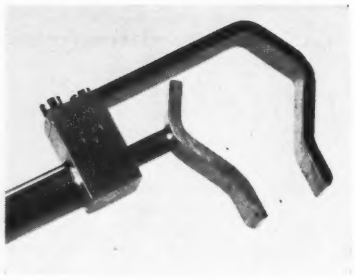
Detachable head remote handling tongs made by Hambling Industries Ltd., one of the Ayling Industries Group companies, are now available in two sizes, with shaft tubes of ¾-in. and ½-in. diameter respectively. Length of the shaft may vary from 6 in. to 6 ft and the jaws can be swivelled.



Equipment for opening thin-walled soft aluminium cans. The main requirement is that the cutter should function with minimum distortion to the cans. Manufactured by Hambling Industries Ltd., Chichester.

For handling of an intricate nature, a tong having a remotely interchangeable head is used in conjunction with lead sphere units. Special heads, interchangeable with the standard ones, permit handling round corners, into transfer ports etc. Various shaped jaws can also be attached to the standard head. Thus a series of heads with appropriate jaws can be placed inside a box and attached remotely as required to suit the particular sequence of operations. The jaws are closed by depressing the trigger in the handle; they can be locked by rotation of a thumbscrew. Lifting capacity can be up to 3 lb. The shafts of these tongs are made of stainless steel with jaws of chromium-plated steel and handles of aluminium.

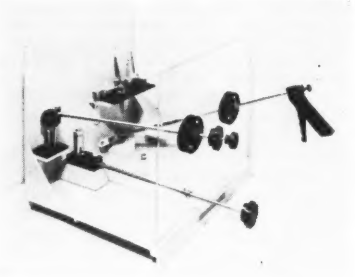
For the opening of such items as standard isotope cans, there are two types of vice. One is based on a conventional unit with the operating screw passing through the shielding wall. The other is self-operating and grips



Close-up of the jaws of a duck head handling tong as used for simple manipulations and transfers.

the can by way of rubber-tyred eccentric wheels which revolve as they come into contact with the can which is itself rotated by a right-angle tool. Hambling Industries Ltd. also manufacture a variety of special tools including vices, can openers and cropping tools.

(Hambling Industries Ltd., Chichester, Sussex.)



H. L. Instruments, Ltd., of Bournemouth, make a wide range of remote handling equipment: sole agents are General Radiological Ltd., 18 New Cavendish Street, London, W.1.

Welding Thick Plate

When welding large vessels with walls of very thick plate it is of the greatest importance to obtain good and uniform physical properties throughout the whole section of the joint. This difficult problem has recently been solved after long and intensive research work in the Murex research laboratories by the development of a new electrode known as the Fortrex 35A.

Plate of up to 1½ in. thickness can, of course, be successfully welded by using the normal low hydrogen Fortrex 35 electrodes and satisfactory tensile, elongation and impact properties can be obtained throughout the full thickness of the weld. These standard electrodes, however, have not been found entirely satisfactory when used for the welding of vessels with 3- to 4-in. thick walls.

The new Fortrex 35A electrode, which has been thoroughly tested, gives all the required properties in the welded joint in extra thick plates and the weld metal has particularly good impact properties at sub-zero temperatures. The electrode also has all the advantages of the standard Fortrex 35. It is an all-position electrode; it is simple to use, slag removal is easy and the radiographic quality of the weld metal is sound.

(Murex Welding Processes Ltd., Waltham Cross, Herts.)

Argonarc Cutting and Spot Welding

The Argonarc cutting process enables aluminium plates 1 in. thick to be cut at high speeds using either oxygen-free nitrogen or other gases. The arc cutting action is produced by a constricted arc of high temperature and velocity being struck between a tungsten electrode and the surface of the metal and surrounded by a shielding gas. The concentrated and columnated energy of the arc stream melts and ejects a thin section of metal to form a kerf. The result is a clean cut edge with little or no adhering dross. A power source giving an open circuit voltage of at least 110 volts enables arc voltages of 66-80 to be obtained at various current settings.

Argonarc Spot Welding

A control system which eliminates cratering, and gives consistent results when welding light gauge materials from one side only has been devised by British Oxygen. A d.c. rectifier is the power source, and crater control is effected by resistances in the magnetic amplifier control circuit. The crater control device reduces the current to zero in four stages.

The equipment used consists of the d.c. power source, timing control, and a torch which is normally held in the hand and is used to position the electrode above the material and supply the argon which shields the weld. A trigger switch incorporated in the gun handle sets in motion the timing circuit and the arc can then be struck for a pre-determined time. The heat from the arc flows over the interface and the fusion of the materials is completed.

The process is applicable to the 18/8 group of stainless steels as well as some new high-tensile stainless steels including FV 520 and FSM1.

(British Oxygen Gases Ltd., Spencer House, St. James's Place, London, S.W.1.)

Birlec Adsorption Dryers

Birlec Ltd. have recently received several orders concerned with nuclear developments. These orders include air and gas drying equipment for three nuclear power plants and a batch of eight special furnaces for U.K.A.E.A.'s Industrial Group Headquarters, at Risley.

For the experimental power project at Dounreay, Birlec are supplying air drying plant for the fast reactor sphere. This plant is to the order of Thermotank Ltd. of Glasgow as part of the air treatment installation to be supplied by them.

The dryer, which will remove more than 30,000 grains of moisture per hour at temperatures up to 90°F, will initially be required to dry the whole volume of 1,030,000 cu ft of air in the sphere. The moisture content of 86 grains per pound must be reduced to 12 grains per pound within a period of 14 days. When the space has been conditioned the moisture content will be maintained at the latter figure by removing the 30,000 grains per hour and also any moisture evolved in the CO_2 adsorption plant. This entails moisture removal even when the relative humidity is as low as 5%, as would be the case when the dry bulb temperature rises to 90°F.

While the equipment must be capable of dealing with this work, its size and weight are limited. The desiccant vessels must be small enough to pass through access doors only 7 ft wide by 9 ft high, and neither vessel may exceed 5 tons gross weight when complete and filled with alumina.

Other Birlec drying equipment, concerned with carbon dioxide gas, is to be installed at Berkeley and the proposed Hunterston nuclear power station.

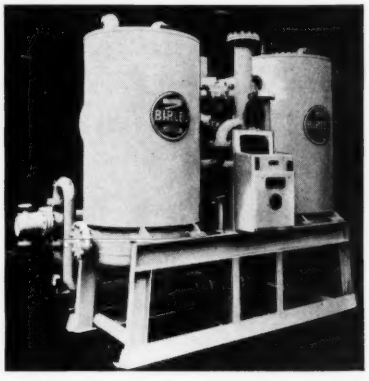
For Berkeley Birlec are to supply eight adsorption dryers and dual heat exchangers, four dryers to operate continuously with each reactor. Their purpose is to prevent condensation and consequent corrosion taking place in any part of the carefully prepared gas system. Each dryer will receive 115 ft³/min of saturated gas, removing 1.25 lb. of moisture per hour. Should a steam coil burst the system can be returned to the required dryness within 12-14 hours.

This type of adsorption dryer consists basically of two cylindrical chambers filled with moisture adsorbent material, which are interconnected by valves so that while gas is being dried in one the other may be reactivated by means of a built-in heater. Thus, with automatic changeover valves, continuous drying is obtained.

Four similar dryers are to be supplied for Hunterston, where they will deal with a charge of 100 tons of CO_2. Each unit will remove continuously a maximum of over 4.2 lb of moisture from a gas flow of 10,200 lb per hour. The moisture content of the original charge will be dried from 0.05% by weight to 0.03% in less than 24 hours, and must be returned to the latter figure promptly after the addition of 1 ton of CO_2 at 0.05% once a day.

The eight Birlec furnaces for Risley will be of a special twin pot design with common heating and air circulation systems. With working dimensions of 15½ in. diameter and 4 ft 6 in. depth, each 80 kW furnace will anneal a charge of 30 metal rods, making up a charge weight of approximately 1,350 lb. The furnaces will have an atmosphere of argon and will operate on an eight-hour-day basis. Time switches are to be incorporated to enable the furnaces to be brought up to temperature before commencing each day's work.

(Birlec Ltd., Tyburn Road, Erdington, Birmingham, 24.)



Birlec process gas drying equipment—typical of the plant which the company has contracted to supply to Dounreay, Berkeley and Hunterston.

Shaping Steel Plate

A 4,500-ton press for shaping heavy steel plates, believed to be the largest and most powerful of its type in Europe, is now in operation at the Darlington works of Whessoe Ltd., one of the eight member companies of the Nuclear Power Plant Co. Ltd. group. At present the press is forming the plates for the two spherical pressure vessels at Bradwell, which will be 66 ft 6 in. in internal diameter, and will vary in thickness from 3 in. to 4 in. Individual plates weigh up to 8 tons each.

The press, designed and built by Fielding and Platt, Ltd., of Gloucester, has an unusually long upward stroke: it is operated hydraulically and has automatic controls. Associated with it are a plate-heating furnace designed and made by Gibbons Bros. Ltd., of Dudley, and a charging machine specially designed and built by the same company.

The press, the plate-heating furnace and the charging machine with its running rails are all erected on a common longitudinal centre line, the press being the central item of the plant. Four charging machine arms carry the plate into the furnace hearth and are then withdrawn. The plates are heated to temperatures up to 1,000° C. When the desired temperature is reached the charging machine arms lift the plate from the hearth and withdraw it on to the machine. The machine then returns on its track until the hot plate is located centrally with the press blocks. The plate is lifted clear of the machine by means of ejector rams in the base of the press so that the machine can be completely withdrawn and pressing can take place. When the press table and bottom block have been lowered, the plate is lifted by the ejector rams and carried away on a special cradle supported by the charging machine.

A 3-in. thick steel plate is ejected from the 4,500-ton press built by Fielding and Platt, Ltd. for Whessoe Ltd.

Subsequently the plate is taken to two special shops, in the first of which it is marked by means of a light projector plant. This system has taken the place of marking off, hitherto the universal practice in steel plate engineering and shipbuilding. The plate is cut to shape and prepared for site welding in the second shop by means of an automatic flame-cutting plant.

The charging machine is 54 ft long and weighs 65 tons. Electrical interlocks prevent the unit entering the press when the table and ejectors are up, and do not allow the press to operate until the machine is fully withdrawn.

The furnace, also built by Gibbons Bros., Ltd., is of fairly straightforward construction but special attention was given to the hearth to enable it to bear heavy loads. Heating is by town gas in a three-zone system. The furnace door is electrically operated with push-button control.

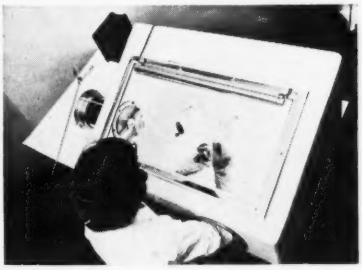
The civil engineering works for the press, furnace and ancillary installations were carried out by Bovis Ltd., London. They included the construction of the deep press pit, which involved the removal of some 2,400 tons of clay and silt from a 45-ft deep excavation.

Radiation Protection

A radiation protection service with consultation on X-radiation protection problems, and technical assistance in planning and equipping complete X-ray departments with all necessary protective measures, as well as the revision of such measures in existing departments, is now offered by Philips Electrical, Ltd.

Other features of the service include the supply of all types of protective media such as lead, lead ply, Philitex blocks (barium sulphate) and protective doors; complete installations to specification; advice on suitable electrical interlocks and other safety measures; the provision of special handling gear for X-ray equipment—this can be integrated with the design and protection of the X-ray department.

(Philips Electrical Ltd., Research and Control Instruments Division, Century House, Shaftesbury Avenue, London, W.C.2.)



A new vacuum cabinet for handling radio-active isotopes by John Bass Ltd. U.K. sales are handled by B.M.B. (Sales) Ltd., Crawley, Sussex.

Nuclear Research

Fulmer Research Institute, which has just celebrated its tenth anniversary, offers British industry an almost unique research service.

Currently, work is being done on several of the nuclear metals. The crystallographic structure of uranium alloys is being investigated, and activity measurements made of U-Bi alloys by hydrogen pressure and effusion methods. Experimental work is also being done on the rolling of zirconium alloys by enclosing a pellet of the alloy in a mild steel sheath which is then rolled and the sheath finally removed by pickling. Pure chromium, similarly sheathed, is being extruded with a view to the production of sections.

Five X-ray generators are in use, and special techniques involving the use of monochromatic radiation have proved useful in the study of age hardening. In addition to the normal high-temperature camera, a special unit has been developed to enable X-ray studies to be made of highly-reactive materials at temperatures up to 1,000° C. and with a vacuum of 1×10^{-7} mm Hg. An example of the use of this equipment is the examination of the horizontal surface of liquid metals such as sodium, potassium, Na-K alloys, and gallium under high vacuum. The monochromatic X-ray beam is focused on to the surface of the liquid metal contained in a stainless steel crucible under high vacuum and the diffracted intensities recorded with Geiger counters and scalers.

High temperature creep studies of low alloy steels are being made, and creep tests are being carried out in compression and in special atmospheres on uranium and its alloys. A brief survey of packaged reactors for isolated sites has also been made.

(Fulmer Research Institute, Fulmer, Bucks.)

Surface Heater

Surface temperatures of up to 1,000° C. are said to be obtainable with a new flexible heating device introduced by Electrothermal Engineering, Ltd. Designed for use where large surface areas have to be subjected to high temperatures, the heater is built up from a network of resistance wires insulated by interlocking high - temperature - resistant ceramic blocks. Each measures $\frac{3}{4}$ in. by $\frac{5}{8}$ in. and is $\frac{5}{16}$ in. thick.

Although securely attached to adjacent blocks, each individual block functions independently. This method of construction is said to give such a high degree of flexibility that the heaters can be applied to parts with diameters as small as half an inch. The heater is made to specification in sizes up to 48 in. by 48 in. Two or more heaters can be linked together to cover larger areas.

(Electrothermal Engineering Ltd., 270 Neville Road, London, E.7.)

The new flexible heater for high temperature operation, developed by Electrothermal Engineering Ltd.

Patents Reviewed

These abstracts have been made from British Patent Specifications, complete copies of which can be obtained from the Patent Office, 25 Southampton Street, London, W.C.2, at 3s. 6d. each (including postage).

B.P. 771,294. Radioactive materials. Isotope Developments Ltd., E. N. Shaw.

Radioactive cobalt gives rise to γ-rays and β-rays but usually most of the β-radiation is absorbed within the body of the source so that predominantly γ-rays emerge. It has been found that the β-radiation can be substantially increased by using a thin film of cobalt of a thickness not greater than 0.002 in. Such β-radiation is specially useful for determining the thickness of films in the range of 2 to 20 milligrams per sq. cm. (See B.P. 677,451). Although the γ-radiation does not present a health hazard, a removable shielding may be convenient.

B.P. 772,404. Nuclear reactor. To: Varian Associates (U.S.A.).

The power that can be generated from an atomic reactor of a given size is limited by the heat that can be removed, in the direct boiling-water reactor, the heat that can be removed by the steam without carrying some of the fuel contents of the moderator along with it. In order to increase the size, i.e., the removable amount of steam, the reactor is rotated at a speed sufficient to maintain the fluid against the inner walls of the reactor due to centrifugal force. Fig. 1 shows a symmetrical or balanced type of the rotating boiler reactor in which a common shaft 1 carries the rotating reactor 2 and the two turbine sections 3 and 4. The hollow reactor body 5 ends on both sides in spaced radial spokes 6 on hubs 7 and 8. A shielding 22 (lead) envelops reactor and turbine sections. For breeder purposes, this shielding may contain uranium or thorium. Before the reactor is set in operation the mixture of coolant (heavy or light water) and fuel (enriched uranium) is stored in a sump which has control rods. The reactor is first set into motion by a starting motor through a clutch mechanism and a pump delivers water and fuel to the annular troughs 9 and 11 through pipes 19. The liquid overflows between spokes 6 into the rotating body 5. The chain reaction commences and steam is produced and passes through passage 18 into the turbine. The expanded steam is led through conduits 21 to a condenser and then returned to the sump and pumped back to the rotating reactor. On reaching a certain speed the starting motor is decoupled. The reactor water and the fission fuel is held against the inner walls and no working fluid and fuel particles leave the reactor body 5. The design may be modified by an integral arrangement of a turbine with the rotatable reactor from which the steam then passes to the turbo-generator which rotates independently of the reactor.

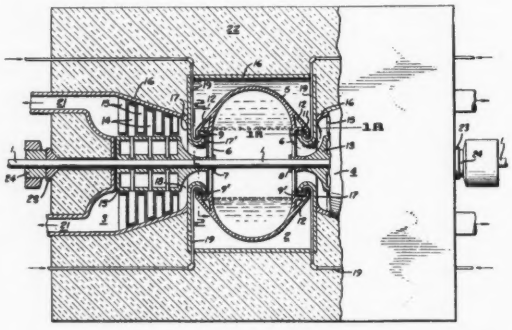


Fig. 1.
B.P. 772,404.

B.P. 772,544. Apparatus for producing pulses in fluids. L. Hack. To: U.K. Atomic Energy Authority.

A glandless apparatus with only a single moving part having a large clearance fit (to avoid seizure by solid particles in the fluid) in its sealed chamber as part of the pipe line. The moving part is a (soft iron) plunger oscillated between soft-iron stop rings by an external electromagnetic system of four symmetrically arranged laminated cores with A.C. windings. A pulsing rate of up to 200 pulses/min. is obtainable, e.g., in counter-current packed extraction columns.

B.P. 772,617. Chemical treatment of plutonium hexafluoride and uranium hexafluoride. R. Hurst, H. K. Ray. To: U.K. Atomic Energy Authority.

If plutonium hexafluoride or uranium hexafluoride vapour is passed into strong (98%) sulphuric acid, a sulphate of plutonium or uranium becomes deposited as small crystals from the sulphuric acid. The process may be used in connection with a homogeneous nuclear reactor with a solution of uranyl sulphate and a thorium oxide blanket. Uranium hexafluoride extracted by means of fluoride from the blanket can then be converted into uranyl sulphate for the reactor core.

B.P. 772,702. Fuel element charging/discharging gear for nuclear reactors. E. Long. To: U.K. Atomic Energy Authority.

As in a moderator structure, dimensional changes occur due to thermal and irradiation growths within its lifetime and also impact with any hard object must be avoided; a guide is required for passing fuel elements into and from their channels in the moderator structure. The new charging guide presents a symmetrical array of (16) parallel channels on a three-point support against the face of the moderator with central boss for locating the guide co-operating with a radial (sliding) key.

B.P. 772,859. Clad steel plates. To: Lukens Steel Co. (U.S.A.).

Zirconium-clad steel plates with an iron or nickel layer in between. One side of a zirconium sheet is electroplated with iron or nickel. One side of a steel plate is coated with a parting material and placed with the coated side on the unplated surface of the zirconium sheet. A second steel plate is placed on the plated zirconium face, and the pack hermetically sealed. An inert gas is then blown through the pack while the assembled plates are heated. The pack is then reduced, e.g., by rolling, to bond the zirconium sheet to the second steel plate.

B.P. 772,867. Leaching of uranium ores using alkali-metal or ammonium carbonate and bicarbonate. To: Minister of Mines and Technical Surveys of Canada (Canada).

It has been found that a continuous supply of oxygen and carbon dioxide efficiently maintains oxidizing conditions during the leach and sustains the bicarbonate content of the leach solution. The process enables the extraction of uranium without the necessity of operating under greater than atmospheric pressures.

B.P. 772,991. Forced recirculation steam generators. K. H. Reppel. To: La Mont International Assoc. Ltd.

Especially applicable to steam generators heated by gases at a pressure above atmospheric pressure, e.g., by gases emanating from gas-cooled nuclear reactors. The external casing is generally of circular cross-section; the most suitable form of the gas passage, however, has a rectangular cross-section in order to obtain equal heating of all the steam generating elements. Baffle walls are used for changing the gas passage from circular to rectangular cross-section, these being formed by closely pitched parallel tubular elements through which boiler water at saturated steam temperature is circulated by a pump. The distributor and collector headers to which these elements are connected as well as those for the superheaters and economizer elements, may be installed within the pressure-tight casing so that only one penetration per header is required.

B.P. 773,343. Nuclear reactor and reactor tube therefor. To: Stichting voor Fundamenteel Onderzoek der Materie (Netherlands).

Refers to reactors with a multiplicity of fuel passages through which a suspension of fissile material in a carrier liquid is circulated. It is not easy to maintain a high concentration of nuclear fuel (for the critical state) in the core, because such concentrations are viscous and difficult to circulate. Where the fuel suspension enters the reactor at a single point, and leaves at another single point, the system of reforming the concentrated suspension in a hydrocyclone thickener, as described in B.P. 757,015 (NE 1956 Vol 1(9), p.400 (Dec.)) is suitable. This, however, is not satisfactory in heterogeneous reactors, with a multiplicity of separate passages surrounded by a moderator. In such a reactor, a hydrocyclone thickener is to be located above each of these passages. Pipes for conducting the overflow fractions extend downward with openings at various points so that they discharge into the thickened suspension at or near the bottom of the reactor; the suspension leaving the reactor in a diluted condition, to be passed upwards back into the hydrocyclones.